POWER PLANT ENGINEERING

GENERATION - TRANSMISSION - DISTRIBUTION - UTILIZATION

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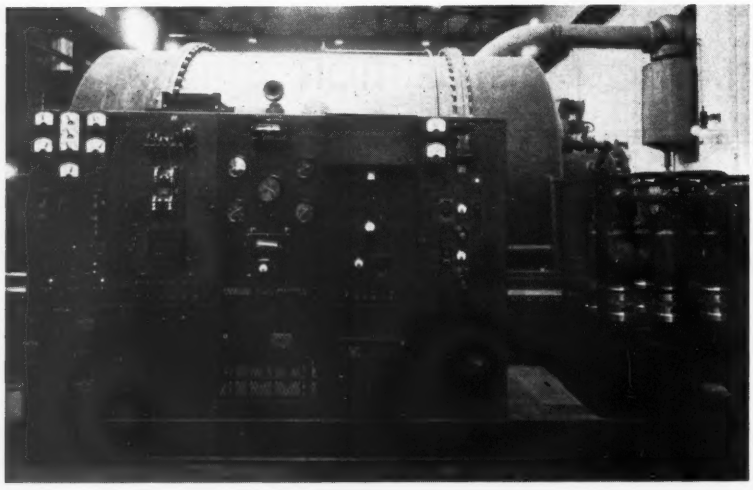
TUBES—Here They Are in the Power Plant



WELL, HERE THEY ARE; electron tubes in the power plant. It is not good form to indulge in "I told you so's" but we have been preaching the use of electron tubes in the power plant for so many years that we cannot resist this opportunity to point out the soundness of our predictions. From the time the electron tube first began to revolutionize the field of electrical communication, its enormous possibilities in other fields became apparent and at the risk of being regarded visionaries, we advocated their use in the field of heavy power transmission. Tubes have, of course, been used to an increasing extent in power plants and in industry in connection with control apparatus, but they have never been considered equipment of major importance. The tubes used involved currents of an ampere or two, indeed, most of them carried milliamperes.

Here, however, in the installation pictured above, we have a group of tubes, metal clad affairs resembling shells for 16 in. guns, which carry currents of 600 amperes! Nor are they for mere purpose of control or regulation. They are that, of course, but their primary function is that of furnishing the full exciting current for this 15,000 kv-a. hydrogen-cooled, synchronous condenser. In other words, these electron tubes entirely displace all rotating excitation equipment.

Experimental? Only in the sense that it is the first installation of its kind. Actually, it has been in operation with outstanding success since August 1933—just two years. There is nothing fragile about them. They are rugged affairs, with steel shells and massive bases, built to take their place alongside of any orthodox power apparatus; they may be counted on to hold their own in any emergency.

We will not discuss their performance record here; that is amply covered in Philip Sporn's article on page 458. Their performance, however, clearly indicates that tubes are destined to become more than just interesting gadgets around power plants. They are "going places." This is the beginning. Mr. Sporn and his associates in the American Gas and Electric Co. deserve high praise for their courage and foresight in developing these pioneer applications of electron tubes for power plants.

* * * *

It is a long time since an installation of major size was made in a steam electric central station in this country but in this issue we are pleased to present a complete description of the new 165,000-kw. addition to Richmond Station of the Philadelphia Electric Co.

Richmond Station is scarcely ten years old but we have only to compare the equipment comprising the new installation with that in the old to be impressed by the progress that has been made in these years. The original generating units were rated at 50,000 kw. The new unit is rated at 165,000 kw. but is installed in the same space as that required for one of the old 50,000-kw. machines: three times the capacity in the same space! A similar condition prevails with respect to the new boilers. Two of the new boilers occupy the same space as four of the old boilers but these two new boilers having several times the steaming capacity of four old units.

Several years ago it may be recalled, there were several disastrous turbine oil fires in central stations. These fires indicate the need for certain changes in design of the lubricating and governor systems. Instead of oil in the turbine governor system, the new Richmond unit uses Aroclor—a non-inflammable liquid which effectively eliminates all danger of fire from this source.

These are merely a few of the many interesting features of the new Richmond unit. There are many others—the new box bus with amortisseur bars, the modified bin arrangement in the boiler room, the all-welded high pressure steam lines, items which can only be mentioned here, but all of them are discussed in detail in the leading article in this issue.

With the Editors

Strikes in Power Plants

NO FINER spirit exists in industry than that commonly displayed between employers and employes in the power plants of this country. Throughout the entire history of electric power generation controversies between workmen in power plants and their employers have, as a rule, been settled amicably without interruption of power generation. Such a record is worthy of praise for all parties concerned, particularly during times of rapid economic and social changes such as have been experienced during the past five years. This tranquility has been broken somewhat, however, in the past few months by a severe strike in the central Illinois district and another of less proportions in Toledo.

Without discussing the merits of either of these recent controversies, it behooves every individual connected with power generation to study the entire situation and the possible outcome of proposed changes in conditions before committing himself to a course of action that may lead to strained employment relations.

Power plant employes are in a peculiary distinctive situation in that they are depended upon to perform their work faithfully not only by their employers but by all others who use the services rendered by the plant. A score of power plant employes by a walkout may be able to stop the work of several hundred in a factory plant or throw a whole city into a chaotic condition if a utility plant is the one affected.

Although the financial responsibility of keeping a plant running rests squarely with the plant owners and management, a very definite moral responsibility rests with the engineers charged with the care of power plants to keep them running according to schedule. The community at large—fellow workmen, neighbors, merchants, bankers, affected citizens in general —will pass judgment on any act of engineers which is a direct cause of a power plant shut down that interferes with their own work, convenience or pleasure.

In most cities and many states power plant engineers are protected from incompetent competition by license laws placing them out of the class of tradesmen and into the class of professional men whose value to an employer cannot justly be measured by the amount of time spent on a job but by the exercise of their skill in keeping the plant running continuously with safety and economy. Failure of an engineer to live up to the responsibilities of his position may be just cause for taking away his license. Engineers have worked hard to secure license laws and up to the present time no noteworthy abuse of these licenses has been noted but their holders must guard the privileges they enjoy by serving their communities in a highly commendable manner or the license laws may be repealed as a result of public demand.

Controversies over wages, hours of work, physical and sanitary conditions of working quarters, unemployment insurance, pensions and insurance are bound to arise with changed social and economic conditions but, with a desire on both sides to be fair, a way can usually be found to adjust differences through a full and free discussion of existing conditions by interested and responsible persons without a walkout.

The great danger in controversies of this sort is the tendency of employes to put their case in the hands of a professional agitator whose tactics are militant and extreme and whose responsibility to the community ends with his fee for services. The consequences of a power plant strike are too severe to place the entire management of a controversy into the dictatorial hands of a representative who does not carry a personal responsibility to the community. Advice and council under such circumstances is essential but authority to act should remain with the engineers.

Rapid changes in the cost of living, reduced hours of work, the failure of the N. R. A. Codes, the enactment of the Wagner Labor Disputes Bill, passages of social and industrial legislation in various states, the tightening of control on private electric utilities, extreme and uncertain changes in tax rates, competition created by government subsidized power plants are conditions affecting both employer and employe in the power plant field and requiring the exercise of extreme tolerance on all sides if amicable solutions are to be reached without irreparable loss to communities and detriment to the engineering profession. The key to this situation is in the choice of leadership and the most trustworthy leader is the one who would lose most, financially and professionally, by a failure of his plans to accomplish equitable results.

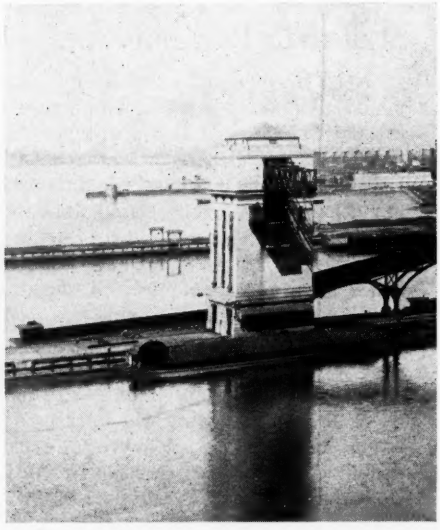
Art and Science

ENGINEERING, although based on science, embodies more than a touch of art inasmuch as the scientific principles require considerable modification in their practical application. From the manufacturing standpoint, the estimator bears equal responsiblity with the designer because, to be a commercial success, the equipment whatever it may be, must not only perform its function to the satisfaction of the purchaser but must also show a profit to the manufacturer. The high state to which this phase of engineering has been developed is well illustrated by the new Richmond 113,000 sq. ft. condenser, the World's Largest.

This unit is installed with a counterweight support which, on occasion, may be used as an accurate scale. After installation, the condenser with water passages filled was weighed and found to be within 300 lb. of the weight estimated before the unit was built. The total weight amounts to over 600,000 lb. and an error of 300 lb. represents an accuracy of better than one part in 2000. This is, of course, beyond the accuracy of the weighing equipment but this need not detract from the glory of those who made the estimates.

NEW 165,000-KW. ADDITION A

Two new 600,000 lb. per hr., slag tap, pulverized coal fired boilers and a 165,000-kw. turbine over a 113,000 sq. ft. condenser more than doubles the capacity of Richmond Station of the Philadelphia Electric Co. The new equipment installed in the space originally laid out for 50,000 kw. reduces by more than a third the volume requirements per unit of capacity. A view of the station from the Delaware River is shown at the right. A considerable portion of the power requirements of the electrified Pennsylvania Railroad system is supplied from this station through the converter substation which appears in the photograph at the right of the power plant



By N. J. WALKER, Project Engineer, Mech. Div., Philadelphia Elec. Co.
W. B. MORTON, Project Engineer, Elec. Div., Philadelphia Elec. Co.
H. GROOTHUIS, Engineer, Power Div., United Eng. & Constructors, Inc.

IN 1925 THE Philadelphia Electric Co. commenced operation of their new Richmond Station, located on the Delaware River approximately seven miles northeast of the heart of Philadelphia. From a survey, made prior to the construction of this station, the conclusion was reached that employing steam conditions at the turbine throttle of 375 lb. ga. and 675 deg. F. would produce the most desired results. The station was designed for an ultimate capacity of not less than 600,000 kw. to be built in three sections. The building for the first section was completed at that time,[1] housing two 50,000-kw. turbo-generators (since rerated to 60,000 kw.) served by 12 stoker-fired, bent-tube boilers, each of 15,697 sq. ft. effective heating surface with economizers and air preheaters.

165,000 KW. LIMIT OF AVAILABLE AREA

In this first section, the turbine room and boiler house were large enough to accommodate four turbo-generators and 24 boilers, anticipating that the additional capacity would be required within a short period. Development of the hydro-electric project at Conowingo and the construction of the steam generating station at Deepwater, N. J., retarded the contemplated program of completing this section.

When forecasts indicated that increased capacity was required to serve expected load growth advantage was taken of the development in the art with regard to size and efficiency of generating equipment. The largest machine, 165,000 kw., offered by the manufacturers for installation in the limited space available at Richmond, was selected for the new unit. This machine occupies the space originally allotted to one 50,000-kw. unit. Richmond was chosen for the location of the new turbo-generator because of the relatively large increase in load demands in this area, together with the ample transmission capacity feeding into the system at this point. In addition, the space available in the existing buildings offered attractive reductions in incremental costs per kilowatt of new capacity, compared with erection of an entirely new station. Consideration was also given to the increasing importance of the load at this station, particularly in view of the expected ultimate of 120,000 kw. in frequency converter capacity to supply Pennsylvania Railroad electrification.

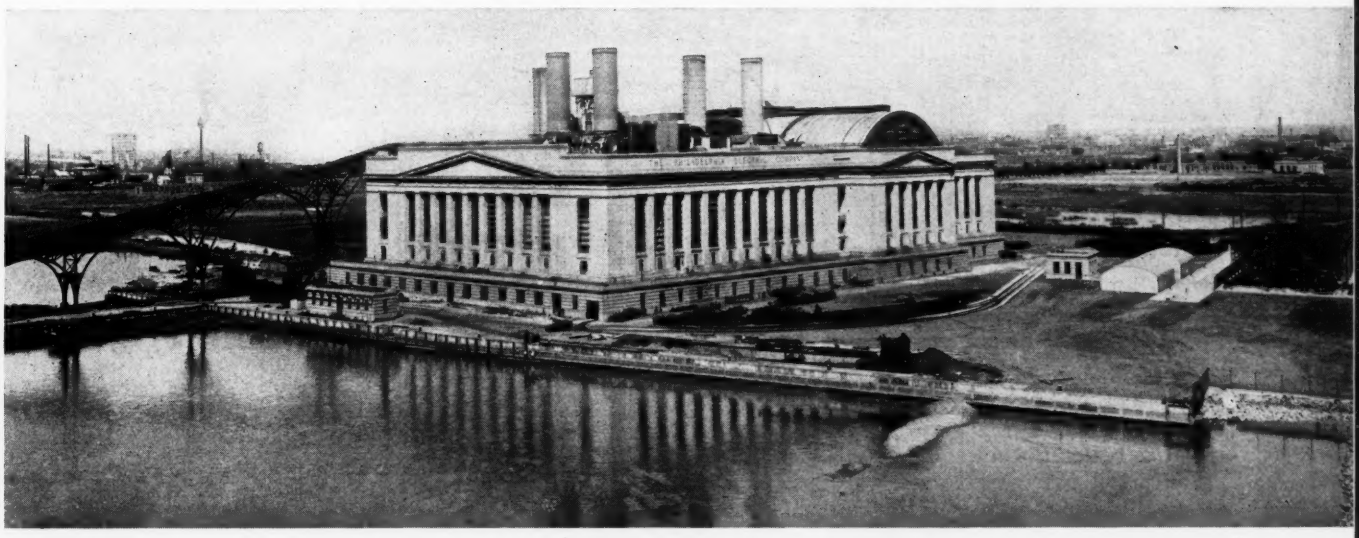
ORIGINAL STEAM PRESSURE RETAINED, TEMPERATURE INCREASED TO 850 DEG. F.

The amazing progress in the design of turbo-generators[2] is exemplified in the placing of a 165,000-kw. machine and its auxiliaries in substantially the same space originally intended for one of 50,000-kw. capacity. Many new and interesting problems have arisen out of the complications involved in fitting a unit of

[1] Richmond Goes on the Line with 100,000-Kw. Power Plant Engineering May 15, 1926, p. 564.

[2] Details of the turbine, the generator and the condenser will be given in subsequent articles in Power Plant Engineering.

N AT RICHMOND STATION



this size into the space designed for a machine of less than one-third its capacity.

Several studies were made to determine the most advantageous steam conditions to be used for this new unit and it was finally concluded to retain the same throttle pressure as used in the original installation, nominally 400 lb. per sq. in., but to use the highest steam temperature, 850 deg. F., for which standard equipment could be obtained.

Loads in Excess of 135,000 Kw. Will Require Steam from Old Boilers

Studies further revealed that the installation of two pulverized fuel fired boilers, each with an output of 600,000 lb. of steam per hr., about the largest capacity which could be installed within the existing column spacing, would be the most economical for this installation. This steam output is sufficient to carry a load of 135,000 kw. on the turbine. Additional capacity can be carried on this unit by drawing steam from the existing boilers. The installation of additional boiler capacity was thus deferred until the increased power demand requires it. From the new boilers steam may be utilized on the existing turbines by passing it through a desuperheater. This will at times be desirable on account of the lower cost of the coal contemplated for use in the pulverized-fuel fired furnaces.

Last Blades Faced with Stellite

All boiler and turbine auxiliaries, with the exception of an auxiliary turbine-oil pump and the existing spare boiler-feed pumps, are motor-driven. The turbine[2] is a tandem compound unit with 46 rows of rotating blades, 30 rows being in the high-pressure cylinder. The low-pressure element is of double-flow design with eight rows of rotating blades in each path. The turbine blades are of stainless steel with milled heads, except the last three rows of stationary blading on each end of the low-pressure turbine, which have stainless steel blade portions cast into cast-iron bases. Blades in the last rotating row in each path are faced with Stellite to minimize erosion. These blades are 38 in. long and will have a tip speed of 72,600 ft. per min.

The speed of the turbine is controlled by a hydraulic governor, of design customarily furnished by the manufacturer for machines of large size. The impulses of the governor regulate the pressure of a non-inflammable liquid used for controlling the governor valves. There are seven governor valves, two primary valves for loads up to 75,000 kw., one secondary valve for loads from 75,000 to 105,000 kw., two tertiary valves for loads from 105,000 to 130,000

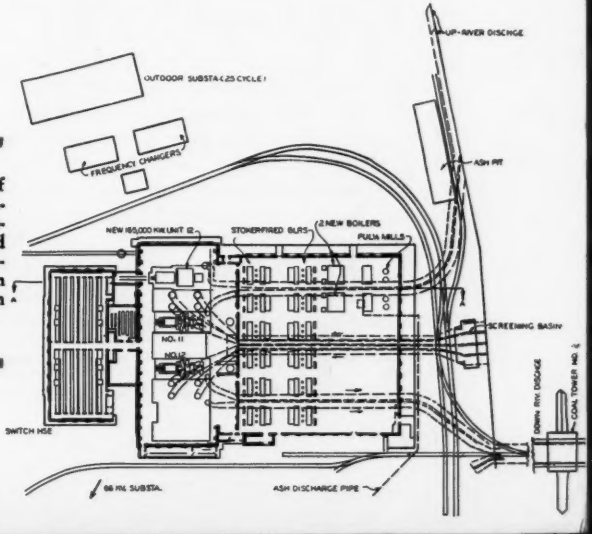


Fig. 1. Plan of Richmond Station showing location of old and new equipment. Section A-A is shown by Fig. 3.

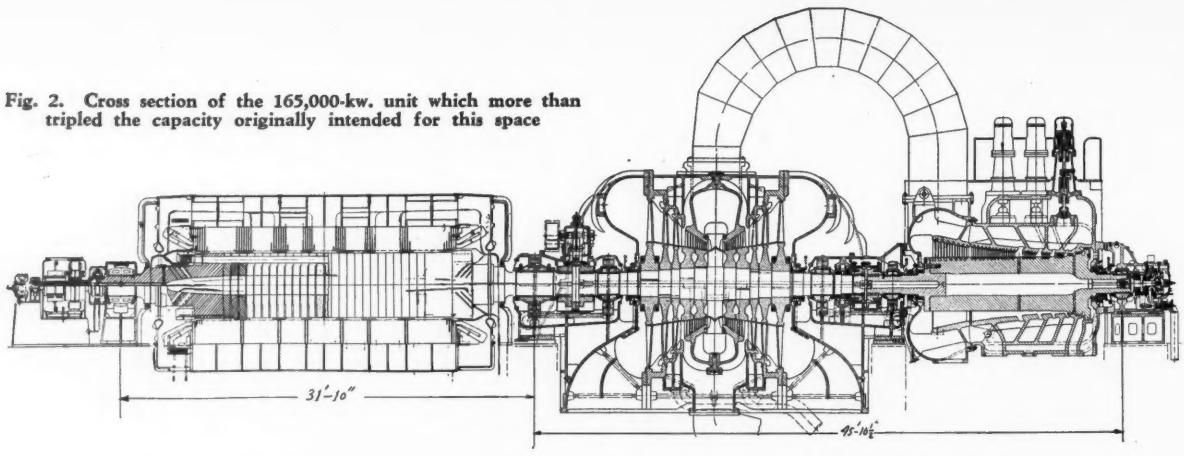


Fig. 2. Cross section of the 165,000-kw. unit which more than tripled the capacity originally intended for this space

kw., and two quarternary valves for loads above 130,000 kw.

Fireproof Room for Lubricants Reduces Fire Hazard

A non-inflammable liquid, Aroclor, is used in the governor system to reduce the fire hazard which exists in handling oil in proximity of hot surfaces and for the same reason the oil tank, oil coolers and the Funk-De Laval oil purifying equipment are enclosed in a fireproof room remote from the turbine. A spindle-turning gear is installed to assist in the distribution of heat throughout the turbine when starting, decreasing the time usually required to bring the turbine up to speed.

In addition to the usual complement of indicating and control devices required for operation of the turbo-generator, instruments are provided for measuring and recording vibration in generator bearings, eccentricity of the turbine spindle, axial expansion of the turbine cylinder, and for indicating noise in the turbine glands.[3] These instruments operate from a high frequency (360 cycles) source. Leeds & Northrup Micromax recorders furnish a record of eccentricity, vibration and expansion, and indicating instruments in parallel with these give instantaneous readings. These recorders and indicating instruments, together with the noise indicator, are located on the turbine control board within view of the operator at the turbine throttle.

Extraction Heaters

The turbine is provided with four bleed points for feedwater heating. The lowest pressure bleed is extracted before the last wheel and is installed primarily to assist in removing moisture from the turbine steam. The feedwater heating cycle is a closed system, the condensate being deaerated in the condenser hotwell and heated in closed vertical feedwater heaters to 325 deg. F. at which temperature it enters the boilers. Make-up for the feedwater is obtained from an evaporator. The steam for the evaporator is taken from the high-pressure bleed point and the vapor is condensed in the feedwater heater taking steam from the next lower bleed point.

The exhaust steam from the turbine is condensed in a single-pass surface condenser,[2] having 113,000 sq. ft. of cooling surface, the largest condenser ever built. The shell is of welded steel plate construction provided with cast-iron water boxes. Practically the entire weight of the condenser is carried on counterweighted levers, which will maintain under all temperature conditions a constant turbine flange loading. The de-aerating hotwell consists of two cylindrical tanks with a storage capacity of 20,000 gal. This hotwell serves as a surge tank in the boiler feed system.

Existing intake and discharge tunnels for the circulating water was used as far as possible. Only a slight change was required to accommodate the single-pass condenser to the tunnels, which were originally designed for a two-pass condenser. Due to limited floor space for this large unit, it was found desirable to install vertical propeller-type circulating pumps. One advantage of this type pump is the continuous submergence of the propeller at all tides.

Vertical Propellor Type Circulating Pumps Require Little Space

Two variable-speed condensate pumps, one a spare, are installed. They are driven by constant-speed squirrel-cage motors. Variable pump speed is obtained by means of hydraulic couplings between the motors and the pumps. The condensate pumps deliver the condensate at a maximum pressure of 175 lb. to the

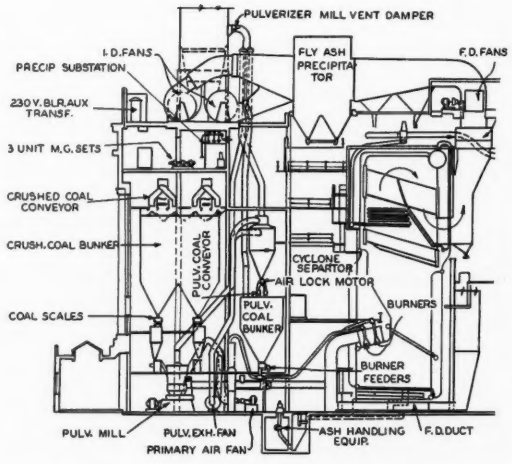


Fig. 3. Section A-A of Fig. 1 showing the arrangement of

[3]See Supervisory Instruments for Steam Turbines by H. Steen-Johnson, W. E. & M. Co., Power Plant Engineering, July, 1935, p. 384, for details of these instruments.

suction header of the constant-speed, motor-driven boiler feed pumps.

The speed of the condensate pumps, and therefore the boiler-feed header pressure, is automatically controlled to maintain a constant excess in boiler-feed pressure above steam header pressure. Three boiler-feed pumps are installed, two of these are required to supply the feedwater to the boilers when full load is carried on the turbine. No additional steam-driven pumps were installed. The existing steam driven spares were considered sufficient for all emergencies.

Steam Jet Vacuum Pumps

Two banks of steam-jet air pumps are provided, each bank consisting of three two-stage ejectors, mounted on a common surface-type inter-cooler and after-condenser, and arranged so that each steam-jet air pump can be operated independently. The steam supply to the jets will average 375 lb. ga. pressure, 825 deg. F.

The two boilers installed are Babcock & Wilcox cross-drum type, designed for 488-lb. steam working pressure. They will be operated with a variable drum pressure to maintain a steam header pressure of 400 lb. ga. The furnace is entirely water-cooled, with side walls of stud-tube design for a distance of 20 ft. above the furnace floor and with bare cast-iron blocks the remainder of the height. The furnace floor consists of tubes covered with bare cast-iron blocks and forms the base for the slag-tap furnace. A large furnace volume, 26,860 cu. ft., was provided in order to limit the heat release to 30,000 B.t.u. per cu. ft. at 600,000-lb. per hr. steam output. A slag screen is provided at the throat of the furnace approximately 15 ft. above the furnace floor in addition to the slag screen type of construction of the lower bank of boiler tubes.

Lower Superheater Tubes of Alloy Steel

The high superheat requires an unusually large superheater and high gas temperatures. The superheater is of counter-flow design. On account of the high metal temperatures the lower tubes of the superheaters are of alloy steel. In one superheater the four and a half lower rows of tubes are chrome molybdenum steel, the other superheater has the two lower rows of tubes of KA_2S (stainless steel) and the next two and a half rows of chrome molybdenum steel.

Each boiler is provided with two forced and two induced draft fans driven by constant-speed motors through hydraulic couplings. The speed of these fans is regulated by automatic combustion control equipment which varies the speed of the fans by increasing

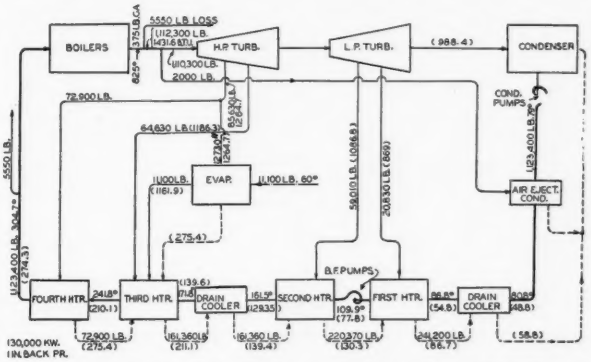


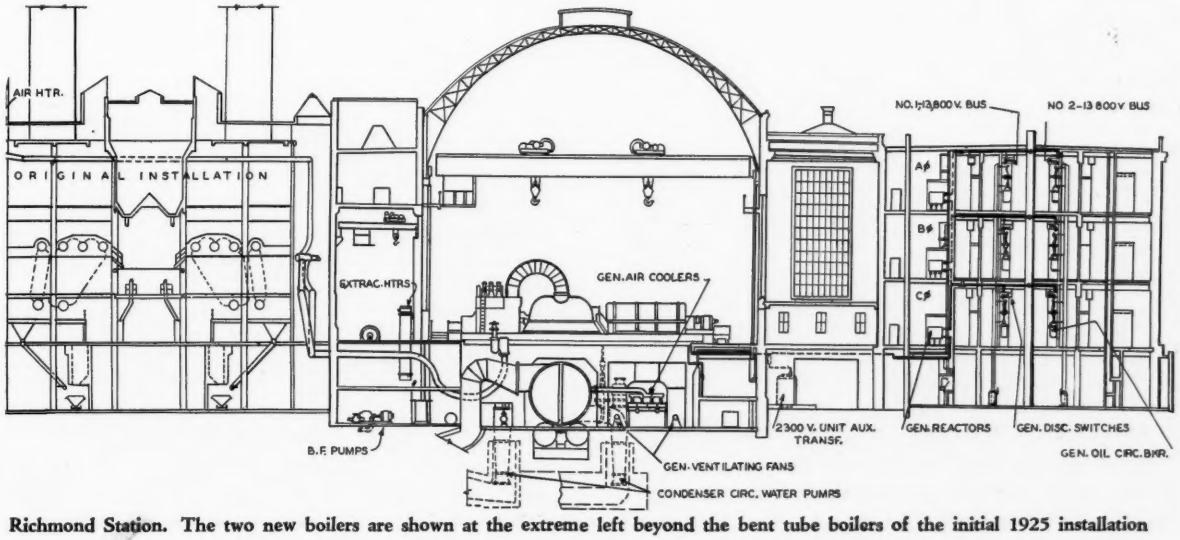
Fig. 4. Heat flow diagram for a turbine load of 130,000 kw., at 1 in. Hg. back pressure

or decreasing the quantity of oil within the hydraulic couplings. The automatic control also regulates the coal feed to the furnace.

Electrostatic Dust Precipitators on Roof

Air for combustion is preheated to about 500 deg. F. by two rotary type air heaters. These reduce the flue gas temperature to 360 deg. F. Fly dust is removed by Cottrell precipitators before the flue gas enters the induced draft fans. The fans and precipitators are located on the boiler house roof; the forced draft fans, the motors and the hydraulic couplings are protected by penthouses; the induced draft fans and precipitators are exposed to the weather.

At 600,000-lb. per hr. steam output, each boiler requires about 30-t. of coal per hour for which two



Richmond Station. The two new boilers are shown at the extreme left beyond the bent tube boilers of the initial 1925 installation

mills are provided each capable of supplying 20-t. per hr. of pulverized coal with a fineness of not less than 70 per cent through a 200 mesh screen. The system is so installed that three mills can supply all the fuel for the two boilers at full load. The mills are supplied with a mixture of preheated air and room air, for mill drying, so proportioned as to maintain a mill outlet temperature of 125 F. to 150 F. Part of the air, after returning from the cyclones, is recirculated through the mills; the remainder is vented

ing the speed of the d.c. motors on the pulverized coal feeders. The burners are installed in two rows and discharge at an angle toward the furnace floor. This type of construction produces long flame travel and maintains a hot slag bed, easy for tapping; it also increases the amount of ash retained in the slag bed. All pulverized fuel preparation equipment is located in a room isolated from the boiler room and is designed in strict accordance with the requirements of the National Board of Fire Underwriters.

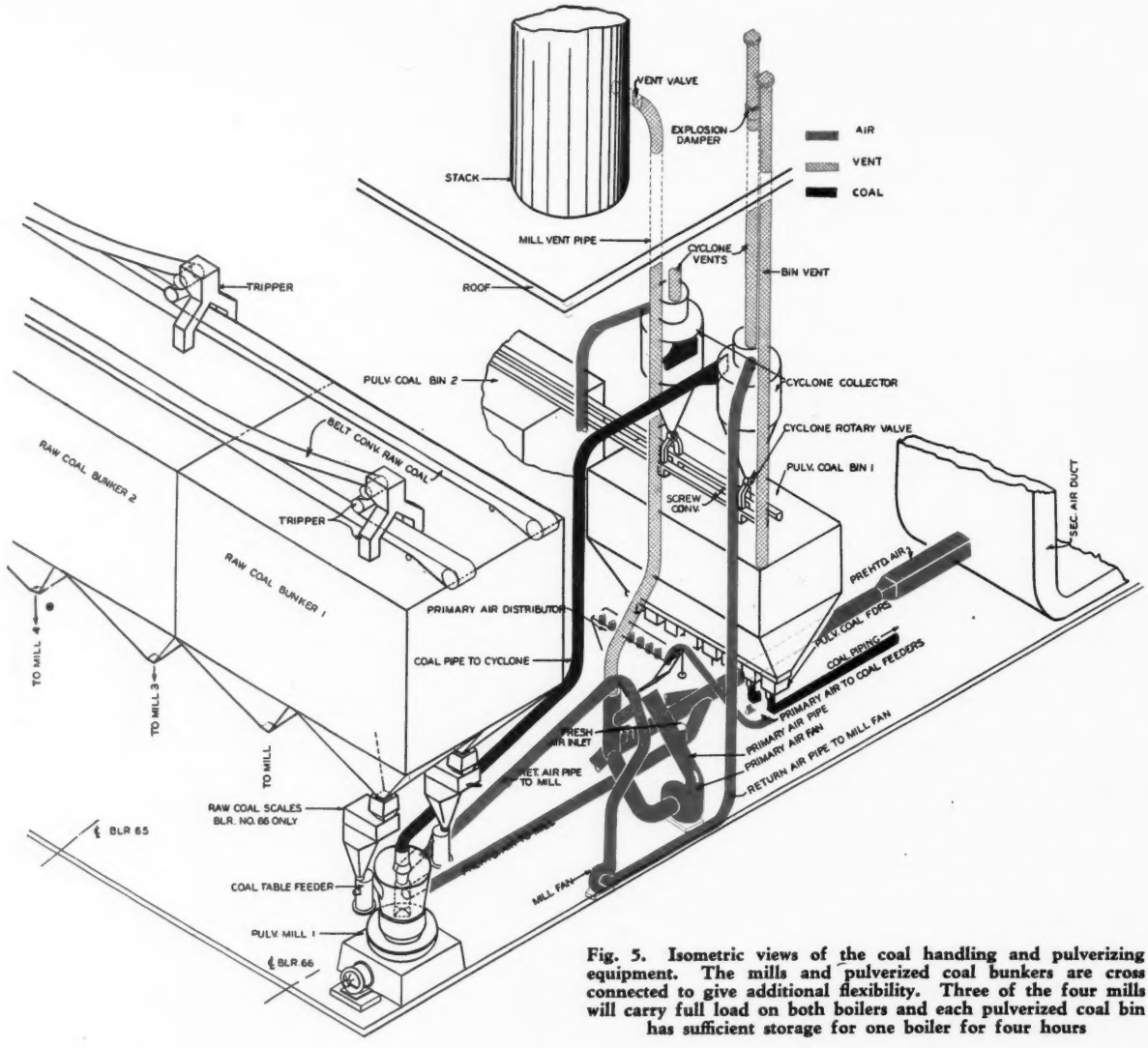


Fig. 5. Isometric views of the coal handling and pulverizing equipment. The mills and pulverized coal bunkers are cross connected to give additional flexibility. Three of the four mills will carry full load on both boilers and each pulverized coal bin has sufficient storage for one boiler for four hours

to the primary air fans and discharged into the furnace.

Cross Conveyors for Pulverized Coal

After passing through the cyclones the coal can be discharged into either of two pulverized coal bins by means of screw conveyors placed under the cyclones. Each pulverized coal bin has sufficient capacity to operate a boiler for 4 hr. at maximum capacity.

Eight burners, each with a rated capacity of 107,700,000 B.t.u. per hr. are installed for each boiler. The rate of flow to the burners is controlled by regulat-

Slag-tap furnaces are expected to retain about 50 per cent of the ash in the coal and most of the fly ash is trapped in the ducts and the Cottrell precipitators. The ash from the slag-tap and the fly ash is conveyed to a concrete ashpit located in the boiler room basement and from there it is pumped to vacant low property adjacent to the plant.

Bunkers Lined with Gunite

The raw-coal handling system consists of two trains of three belt conveyors, each train being capable of delivering 365-t. per hr. of coal from the hoppers under

the old conveyors to the two new coal bunkers. These bunkers are constructed of structural steel lined with Gunite and have a combined capacity of 1600 t., sufficient for 27 hr. of maximum capacity for the two boilers.

Wherever feasible the piping is of welded construction, all steel gate, globe and blow-off valves being welded in the line. The main steam piping from the superheater outlets to the turbine connection contains only two flanged joints, those at the turbine inlets. Each boiler has two 16-in. superheater outlets. These outlets are combined in a special design 16 by 16 by 20-in. non-return valve. The 20-in. steam leads from the two boilers are connected to a 30-in. diameter stub header from which two 24-in. lines feed the turbine. The steam lines required considerable care in design as they passed through the existing boiler house and 16-in. expansion in a horizontal plane from the boiler to the turbine had to be provided for.

Steam mains up to and including 20-in. size are made of Grade B seamless steel pipe. The 24-in. mains are of rolled steel plate construction with longitudinal

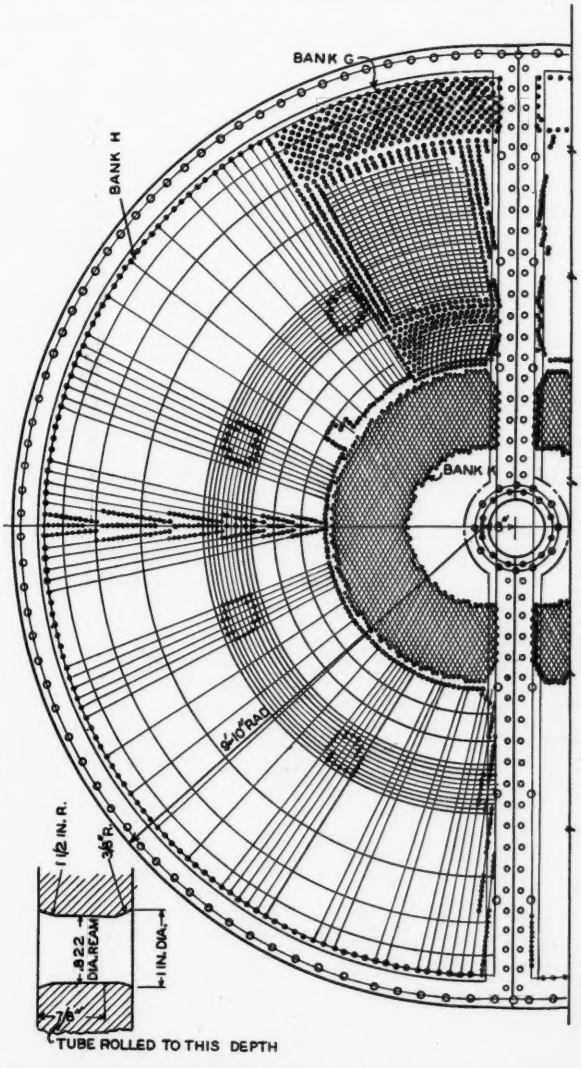


Fig. 6. Layout of the 113,000 sq. ft. condenser tube sheet. Tubes are banked heavy at the top to improve the radial steam distribution

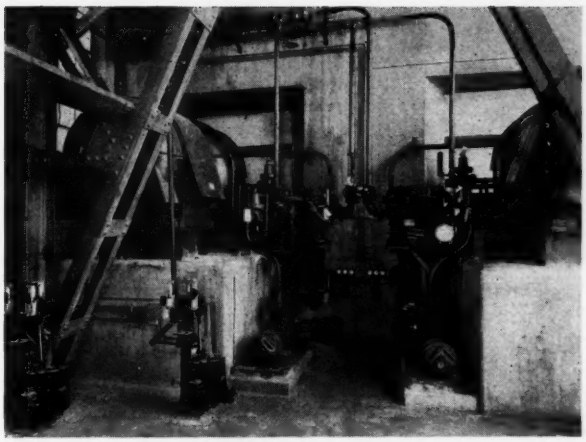


Fig. 7. View of induced draft fan motors, hydraulic couplings, oil coolers and speed control

welded seams. The carbon content of all pipe was limited to 0.30 per cent to facilitate field welding. All shop and field welding on steam and boiler feed piping was performed by certified welders and supervised by Hartford Steam Boiler Inspection & Insurance Co. All welded joints are of butt-welded construction without reinforcing straps and were made by the electric fusion method. Welds in the high-pressure steam and boiler feed lines were stress-relieved by heating with electric resistance coils to a temperature of 1200 deg. F.[4]

Valves Welded In

Valves in the high-pressure, high-temperature steam lines have chrome molybdenum bodies and bonnets, Excelloy seat rings and steel discs faced with copper nickel alloy and nickel steel stems. They are designed for 600-lb. working pressure. Boiler-feed valves are of carbon steel with stainless-steel seats, monel-faced discs, and stainless-steel stems. Small valves for high-pressure steam and drain lines are of forged steel with bolted gland and bolted bonnet, and stainless steel seat and disc.

Exciter Ventilation

The generator[2] is a two-winding machine, one of the largest single-shaft units ever built. Both windings are connected to the same section of the main 13.2-kv. bus. However, since there are duplicate buses, split-bus operation is possible if experience indicates that this arrangement is desirable. The generator is provided with a closed cooling system, using fin-type coolers supplied with air from four propeller-type blowers and water supplied from the condenser circulating system. These blowers operate at high speed, 3500 r.p.m., which requires some form of forced cooling for the bearings. A fan mounted on the blower shaft provides the necessary cooling air. The motor bearings have small gear pumps for circulating bearing lubricating oil.

Mounted on an extension of the main shaft the exciter is ventilated from the generator cooling system. This method of ventilation, tests show, materially reduces the noise from the exciter. The return air from the exciter

[4]Further details of the welding will be published in the 1935 report of the Sub-committee on Boilers of the Prime Movers Committee E. E. I.

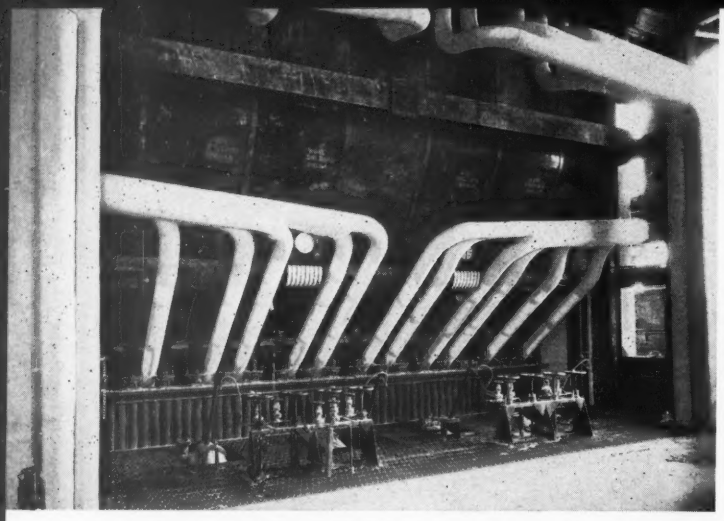


Fig. 8. View of the front of one of the 600,000 lb. boilers from the firing aisle

passes through dry-type air filters to remove any carbon or copper particles given off by collector rings and brushes. Emergency excitation is obtained from the d.c. motor-generator sets, which supply the stokers on the old boilers and which also furnish emergency excitation for the old 60,000-kw. generators.

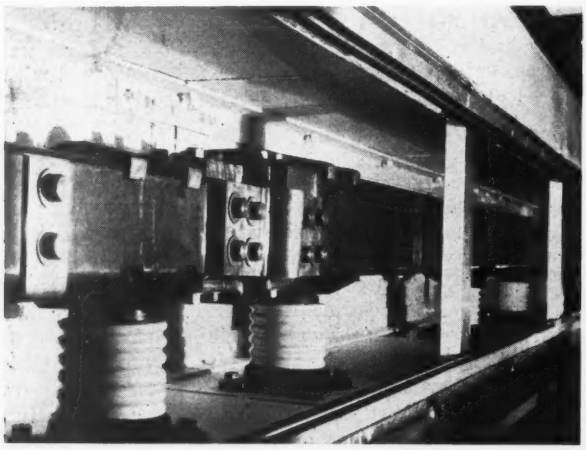
Total weight of the complete stator is 225 t. which required that most of the assembly work be performed in the field. The stator frame was shipped in three sections, two of these stacked in the field, and all winding completed with the stator in place. The rotor, weighing 125 t., was fabricated in the Westinghouse factory. Unusual construction features were employed to avoid the metallurgical problems involved in the large masses of material required for conventional construction using large forgings. Instead of conventional forgings the rotor was constructed of twenty-six 8-in. discs dowelled and bolted together with five bolts, one in the center 13 in. in diameter, and the remaining four 6 in. in diameter. The rotor is handled utilizing an opening in the turbine-room wall, one end riding on a specially constructed carriage. A room beyond the opening serves as a runway for the carriage as well as a repair room for maintenance work on the rotor.

Fire protection for the generator consists of two conventional perforated pipe rings terminated in snap couplings for quick connection to nearby hose connections. Two short sections of pipe, one attached to the top of each end bell, will emit smoke in event of fire.

New Bus Design

The main 13.2-kv. bus is located with its associated switching equipment in a separate switchhouse of vertically isolated phase design. This bus was originally designed for 4000 amp. using up to seven 4 by ¼-in. bars in flat configuration, the assembly housed in alberene stone and steel frame compartments. The old generator leads were designed for 3000 amp. using three 5 by ¼-in. bars also in flat configuration and housed in concrete runways. Runways constructed initially in anticipation of serving the third and fourth generators were used for the leads of the new unit.

Current requirements for the new bus vary throughout its length from 5000 to 7000 amp., and for the new generator leads the currents will, under certain operating conditions, be as high as 4500 amp. These heavy currents precluded the use of conventional flat-bar construction and it became necessary to work up an entirely new type of bus design. After an extensive investigation an assembly of two formed channels arranged face to face simulating the hollow square was selected as the proper conductor for these cur-



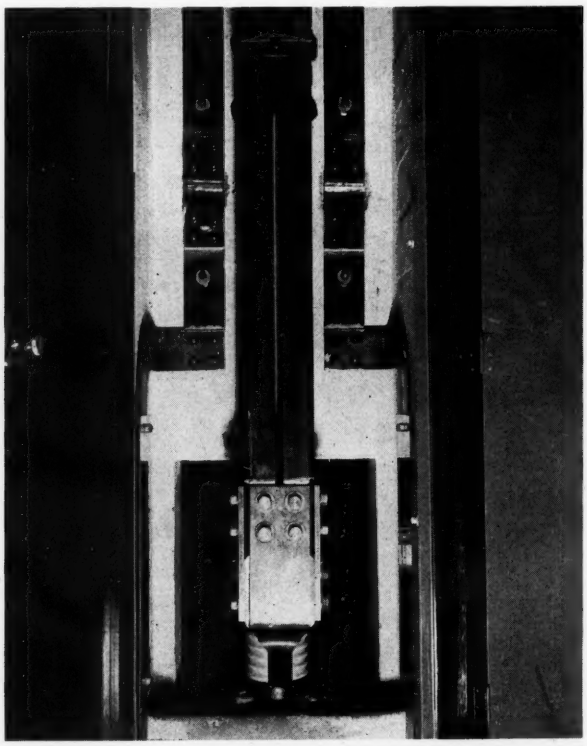


Fig. 9. (Above) Main 13.2 kv. bus showing leafed expansion joints at junction of 6 and 8 in. channel conductors. A feeder tap is shown at the left of the expansion joint. (Right) Generator lead conductor entering reactor compartment. Half inch copper plates are used for these rigid joints. The two amortisseur bars are shown in the rear of the compartment. These bars are provided with expansion joints and slip supports to prevent buckling which might reduce ground clearance

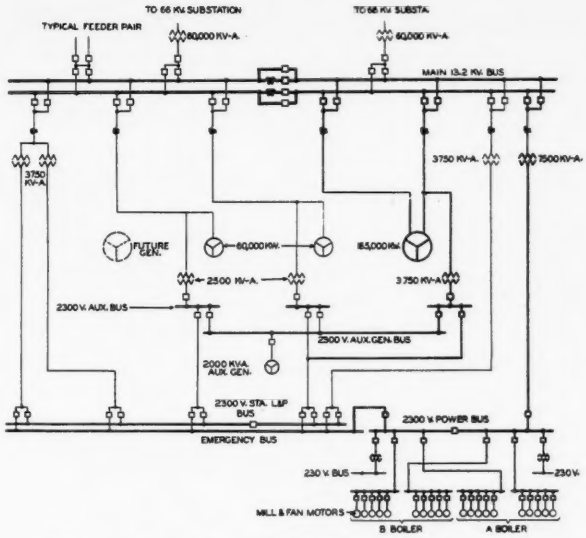


Fig. 10. Single line electrical diagram of the station

rents.[5] Six-inch channels were chosen for the leads and for sections of the main bus carrying up to 5000 amp., and 8-in. channels were used for currents over 5000 up to 7000 amp.[6]

Building Structure Protection from Eddy Currents

In the course of the investigation it developed that serious heating from hysteresis, eddy currents, and induced circulating currents would occur in the building structure and in buried conduit systems in the vicinity of the high-current conductors. Laboratory tests simulating conditions in the field indicated that it would be necessary to provide neutralizing fields to reduce the heating to safe proportions. These fields were obtained by means of continuous amortisseur networks of two 4 by ¼-in. copper bars per phase where steel members paralleled the conductors and with short circuiting copper bands around the steel members where these members crossed the conductors at right angles. Subsequent heat runs showed no harmful heating which indicated that the protective measures were functioning successfully.

Main bus compartments were reconstructed to eliminate the steel framing which was replaced by aluminum sections, each section isolated and insulated from ground except at a single point to reduce heating from circulating currents. All compartment doors in the vicinity of the high currents are constructed entirely of asbestos lumber to avoid heating.

Auxiliary Motor Supply

Design of the auxiliary power system for the new installation follows closely the scheme for the old plant. All auxiliaries are electrically driven. Motors 50 hp. and above are, in general, designed for 2300 v. and below 50 hp. for 230 v. The fan motors and less essential auxiliaries are supplied from an extension of one of the old station light and power buses. This is a single sectionalized metal-clad bus, each section having a separate source of power and serving the auxiliaries for one-half of each of the new boilers. Each section has sufficient capacity to carry both boilers in event of power failure on the other section. This new bus supplies, in addition to the ash-handling pumps and 230-v. service transformers, four group feeder buses. Each of these group buses serves five auxiliaies through non-automatic oil circuit breakers inclosed in steel cubicles namely: pulverizing mill, exhauster fan, induced-draft fan, forced-draft fan, and primary-air fan.

2000-kw. Emergency Generator

Essential auxiliaries (except for one boiler-feed pump connected to the old light and power bus for emergencies) are supplied from a new unit-auxiliary bus. This bus is fed from a transformer connected directly to the generator leads. Emergency ties are provided for connecting the unit auxiliary bus to the old light and power bus or to the auxiliary turbine-generator, an emergency unit provided with the two 50,000-kw. units in the initial installation. This generator, a 2000-kw. machine is quick starting and can be brought to speed ready to carry load in 15 sec.

Fuel flow to the furnace is controlled automatically from the combustion control system by varying the speed of the d.c. motors which regulate the coal supply to the boilers. Speed variation is obtained from a three-wire d.c. system, using three 3-unit motor-generator sets (one per boiler and one spare). One generator of a set supplies the fields of these motors at con-

[5] A 7000 Ampere Bus, H. L. Unland, W. B. Morton, V. R. Bacon, A. I. E. E. Trans., June, 1934.
[6] Channel Bus Solves Space Limitations—W. B. Morton, H. L. Unland, Electrical World, July 7, 1934.

Fig. 11. (Right). View of the up-river portion of the turbine room with the new 165,000 kw. unit in background

Principal Equipment in Richmond Station Extension

Boilers and Furnaces—The Babcock & Wilcox Co. Two single cross drum, sectional water tube boilers with water-cooled slag tap furnaces. Heating Surface, Boiler water-heating 36,216 sq. ft.; superheater No. 65, 15,338 sq. ft., No. 66, 15,100 sq. ft. (101 sections); water wall 4,842 sq. ft. Furnace volume, 26,860 cu. ft., floor area, 737 sq. ft. (29 ft. 6 in. wide). Tube arrangement, 50 tubes wide, 23 tubes high, hot finished seamless steel 4 in. O.D., wall thickness 0.203 in., tubes 25 ft. 10 in. long between headers (total length 26 ft. 0 in.). Drum dimensions, 72 in. I.D. by 37 ft. 9 in. overall, all welded construction, shell 33 ft. 9 in. of 3 in. plate, drum heads 2½ in. plate. Furnace Walls, hot finished seamless steel tubing 3¼ in. O. D., wall thickness 0.250 in. Operating Conditions, max. continuous output 600,000 lb. per hr. at 425 lb. per sq. in. gage and total temp. of 850 deg. F.; feed water entering boiler at 325 deg. F.

Pulverizing Mills—The Babcock & Wilcox Co. Two (per boiler unit) vertical, Type B, constant speed, 20 t. capacity each. Drive, 200 hp., 2300 v., 720 r.p.m. Allis-Chalmers Mfg. Co. squirrel cage motors.

Mill Exhausters—B. F. Sturtevant Co. Two (per boiler unit) 13,000 c.f.m. at 22 in. S.P. (based on 150 deg. F. air). Drive, 100 hp., 2,300 v., 1,800 r.p.m. Allis-Chalmers Co. squirrel cage motors.

Primary Air Fans—B. F. Sturtevant Co. Two (per boiler unit) 22,000 c.f.m. at 15 in. S.P. (based on 150 deg. F. air). Drive 125 hp., 2,300 v., 1,200 r.p.m. Allis-Chalmers Co. squirrel cage motors.

Burners (per boiler unit)—The Babcock & Wilcox Co. Eight per boiler, capacity. 107,700,000 B.t.u. per hr., set in two rows of four each. Drive, ½ to 2 hp., 500 to 2,000 r.p.m., adjustable speed, shunt wound, 230 v. constant potential field, variable potential armature, General Electric Co. motors supplied from three-unit motor-generator sets.

Motor-Generator Sets — Allis-Chalmers Mfg. Co. Three sets consisting of 60 hp., 220 v., 1,800 r.p.m. motor driving a 20 kw., 250 v. d.c. constant potential generator and a 20 kw., 65 to 250 v., d.c. separately excited variable potential generator.

Preheaters—The Air Preheater Corp. Two (per boiler unit) Ljungstrom vertical C.A.N.X. type, each with 24,000 sq. ft. of surface. Rotor drive, 3 hp., 1,750 r.p.m. Westinghouse Elec. & Mfg. Co. motors through Fast's Flexible Couplings, light duty type, size No. 1¼ and Jones heavy duty speed reducers with a 24.5 to 1 ratio.

Boiler Accessories (per boiler unit)

Soot Blowers—Thirty unit automatic valved—Diamond Power Specialty Corp.

Water Columns—Two flat glass columns —Yarnall-Waring Co.

Pressure Gages & Safety Valves—Consolidated Ashcroft Hancock Co.

Non-return Valve—One Schutte & Koerting Co.

Blowoff Valves—Ludlow Valve Manufacturing Co., Yarnall-Waring Co.

Coal Scales—Four Automatic (on one boiler), Richardson Scale Co.

Ash-Handling Equipment — Allen-Sherman-Hoff Co. Hydrojet Slag Handling and Hydrovac Fly Ash Handling Equipment. Two Hydroseal vertical pumps, each will discharge 1,600 g.p.m. through 2,500 ft. of 8 in. pipe. Hydrovactor, 400 lb. of ash per min. Pump drive, 100 hp., 2,300 v., 900 r.p.m. General Electric Co. vertical squirrel cage motors.

Ash Sluice Pumps—Warren Steam Pump Co. Two 8 by 6 in. single suction 1,800 g.p.m., required for sluicing ash from boilers. Two 12 in. Elliott Co. duplex strainers in pump suctions. Drive, 250 hp., 2,300 v., 1,800 r.p.m. General Electric Co. squirrel cage motors.

Condenser and Auxiliaries—Westinghouse Elec. & Mfg. Co. surface condenser, single pass, steel radial flow shell, with cast iron non-divided water boxes and two storage hot wells, total capacity 20,000 gal. Surface made up of 17,700 Admiralty Metal tubes, ⅞ in. O.D. No. 18 B.W.G., 28 ft. 2⅝ in. long furnished by the Bridgeport Brass Co. Tube Surface 113,000 sq. ft. (0.685 sq. ft. per kw. of rated gen. capacity).

Steam Jet Air Pumps—Westinghouse Elec. & Mfg. Co. Two banks of steam jet air pumps, each bank consisting of three 2 stg. ejectors of 10 c.f.m. free air capacity mounted together on a 350 sq. ft. surface combined intercooler and after condenser.

Circulating Pump — Westinghouse Elec. & Mfg. Co. Two vertical self-priming propeller type pumps with a combined capacity of 155,000 g.p.m. at a total head of 16.6 ft. Each pump operating singly will have a capacity of 99,700 g.p.m. against a head of 7.15 ft. Speed 400 r.p.m. Each pump equipped with solenoid controlled brake to prevent reverse operation and driven by a 500 hp., 2,300 v., 400 r.p.m. Westinghouse Elec. & Mfg. Co. vertical squirrel cage motor.

Circulating Water Gate Valves—Chapman Valve Mfg. Co. Two 66 in. motor operated valves.

Condensate Pumps—Ingersoll-Rand Co. Two Cameron three stage horizontal centrifugals, each pump designed for a capacity of 4,000 g.p.m. of 110 deg. F. max. temp. water, taking suction under 29.5 in. of vacuum, max. with 3 ft. net submergence of pump suction above center line. Total head 535 ft. at 1,140 r.p.m. Drive, constant speed 700 hp., 2,300 v., 1,200 r.p.m. General Electric Co. squirrel cage induction motors, through variable speed Hydraulic Coupling Corp. couplings with Viking oil pumps and Andale oil coolers.

Chlorinating Equipment (for circulating water)—Wallace & Tiernan Products, Inc.

Induced Draft Fan Equipment—B. F. Sturtevant Co. Two (per boiler unit) Turbovane induced draft fans, double inlet, with No. 2 by Hydraulic Coupling Corp. couplings, Roper rotary oil pump and Andale oil coolers and SKF spherical roller bearings. Capacity 190,000 c.f.m. each at 380 deg. F. against 14.5 in S.P. Drive, 700 hp., 2,300 v., 900 r.p.m. General Electric Company squirrel cage motors.

Forced Draft Fan Equipment—American Blower Co. Two (per boiler unit) American H.S. forced draft fans, double inlet, with No. 30 Hydraulic Coupling Corp. couplings, Roper rotary oil pump and Andale oil coolers and SKF self-aligning ball bearings. Capacity 102,500 c.f.m. each at 95 deg. F., against 14 in. S.P. Drive, 350 hp., 2,300 v., 1,200 r.p.m. Allis-Chalmers Mfg. Co., squirrel cage motors.

Stacks—Belmont Iron Wks., steel plate type.

Ducts and Breechings—Connery & Co.

Boiler Feed Pumps—Ingersoll-Rand Co. Three Cameron 4 stage horizontal centrifugals, each pump designed for a capacity of 3,000 g.p.m. of 120 deg. F. maximum temperature water against a total head of 1,440 ft. at 1750 r.p.m. Drive, 800 hp., 2300 v., 1800 r.p.m. General Electric Company squirrel cage motors through fast flexible couplings.

Feedwater Heaters and Drainers

No. 1 Heater, Westinghouse Elec. & Mfg. Co., vertical 2 pass, floating head type, 3,000 sq. ft., made up of 1592 ⅝ in. diam. tubes.

No. 2 Heater, Griscom-Russell Co., vertical, 4 pass, floating head type, 6,300 sq. ft. made up of 2000 ¾ in. diam. tubes.

No. 3 Heater—Griscom-Russell Co. vertical, 2 pass, floating head type, 5,000 sq. ft., made up of 1530 ⅝ in. diam. tubes.

No. 4 Heater—Griscom-Russell Co.—Vertical, 2 pass, floating head, 5,000 sq. ft., made up of 1530 ⅝ in. diam. tubes.

Low Pressure Drain Cooler—Griscom-Russell Co. horizontal, 2 pass, floating head type, 2080 sq. ft. made up of 1368 ⅝ in. diam. tubes.

High Pressure Drain Cooler — Griscom-Russell Co. vertical, 2 pass, floating head type, 820 sq. ft. made up of 1064 ⅝ in. tubes.

Float Chambers for Feedwater Heaters—Fisher Governor Co.

Feedwater Heater Drainers—Cochrane Corp.

Evaporator — Griscom-Russell Co. One horizontal Bentube single removable tube bundle type, 664 sq. ft. made up of 166 1 in. tubes. Capacity 25,000 lb. per hr.

Intake Screens—Link-Belt Co.

Coal Conveying Equipment — Link-Belt Co. Two trains of three 36 in. belts (U. S. Rubber Co. belts), each capable of transporting 364 t. of crushed coal at a speed of 350 ft. per min. Equipped with two Stearns 36 in. magnetic pulleys. Drives, 220 v., 1,200 r.p.m., Westinghouse Elec. & Mfg. Co. squirrel cage motors.

Fly Ash Precipitators—Research Corp. Two Cottrell Electric Precipitators each, 3 units in parallel and 2 sections long.

Refractory Boiler Walls—M. H. Detrick Co. Sectionally supported refractory side walls, using General Refractories Co. Salina brick. Insulation one unit, Johns-Manville Superex Blocks and Johns-Manville 85 per cent Magnesia Blocks. Insulation second unit, The Philip Carey Co., Alumino-Hitemp. blocks and The Philip Carey Co. 85 per cent Magnesia.

Main Desuperheater—Smoot Engineering Corp. One 600,000 lb. per hr. nozzle type, 20 in. body to reduce temp. from 850 to 725 deg. F. and equipped with Smoot automatic control.

Auxiliary Desuperheater—Elliott Co. One 50,000 lb. per hr. steam desuperheater, cartridge type, 8 in. line to reduce temp. from 850 to 675 deg. F. and equipped with Bailey Meter Co. air control.

Flood Pump — Worthington Pump & Mach. Corp. One 3,000 g.p.m. vertical, 25 ft. head, 1,150 r.p.m. flood pump, driven by a 25 hp., 220 v., 1,200 r.p.m. Westinghouse Elec. & Mfg Co. vertical squirrel cage motor.

Sump Pump—Yeomans Bros. Co. One duplex vertical sump pump, 250 g.p.m., 25 ft. head, 1,750 r.p.m., driven by a 3 hp., 220 v., 1,750 r.p.m. General Electric Co. motor.

Elevator—Atlantic Elevator Co. Constant pressure, push button type, 1,800 lb. at 100 ft. per min. Drive. 7½ hp., 900 r.p.m., single speed General Electric Co. motor.

Turbine Generator and Equipment—Westinghouse Elec. & Mfg. Co. Turbine-Generator, one two cylinder, tandem-compound, condensing reaction steam turbine and one two winding 165,000 kw., 90 per cent P.F., 1,800 r.p.m., 13,800 v. generator with 45 to 55 per cent distribution between windings. Steam conditions, throttle 395 lb. ga. pressure, 850 deg. F. maximum total temperature. Generator cooling system, closed air system. Fan, four propellor type, 56,700 c.f.m. direct connected to 150 hp., 2300 v. 3500 r.p.m. squirrel cage motors. Air coolers, four Westinghouse Elec. & Mfg. Co. fin type surface coolers, 6050 sq. ft. each. Filters, two sections of American Air Filter Co. dry filter to replace leakage from system. Oil coolers, two 1200 sq. ft. surface, 812 ⅝ in. tubes. Generator excitation, main exciter, 375 kw., 250 v.; pilot exciter, 6 kw., 250 v.

Valves

Atmospheric Relief—Chapman Valve Mfg. Co. Two 42 in., single disc, water sealed poppet type.

Bleeder Check—Crane Co. One 16 and one 24 in.

Alloy Steel Gate Valves—Crane Co.

Carbon Steel Gate Valves—Chapman Valve Mfg. Co.

Iron Globe and Check Valves—Reading-Pratt and Cady Co.

Steel Globe and Check and Small Valves—The Edward Valve & Mfg. Co.

Iron Gate Valves (Small)—Crane Co.

Iron Gate Valves (Large) — Pittsburgh Valve, Fnd. & Const. Co.

One Balanced Regulating Float Control Valve—H. Belfield Company.

Control for Valves—Philadelphia Gear Works, Limitorque.

Control Equipment

Combustion control equipment—Bailey Meter Co.

Feedwater level regulating equipment—Bailey Meter Co.

Feedwater pressure control—Smoot Engineering Corp.

River Water Strainers—Andale Co. Two 3000 g.p.m. rotary type.

Meters and Instruments

Draft Gages, Hays, Paul B. Huyette Co.

Recording Potentiometer Pyrometers, Leeds & Northrup Co.

Pressure, Temperature and Level Recorders, Brown Inst. Co.

Recording Absolute Pressure Gage, Bristol Co.

Venturi Meter (Heater Drains), Cochrane Corp.

Indicating Pressure Gages, Consolidated-Ashcroft-Hancock Co.

Industrial Thermometers, Precision Thermometer & Inst. Co.

Mercury Column Vacuum Gauge—Taylor Inst. Cos.

Combination Feedwater Meters and Boiler Drum Water Level Recorders, Bailey Meter Co.

Boiler Meters (Steam-Air-Fuel Flow), Bailey Meter Co.

Liquid Level Gage (Fuel Oil Tank), Foxboro Co.

Venturi Meter (Boiler Feed), Leeds & Northrup Co.

Oil Separator—The DeLaval Separator Co. (DeLaval-Funk Process).

Piping

High Pressure Steam and Boiler Feed Lines, Grinnell Co.

Low Pressure Service Piping, Benjamin F. Shaw Co.

Water Piping, Toncan Iron, Republic Steel Corp.

Heat Insulation—Keasbey & Mattison Co.

(Continued on page 443)

Principal Equipment in Richmond Station Extension

(Continued)

Turbo-Generator Unit Auxiliary Bus, Station Light and Power Bus Equipment—General Electric Co. Metal clad, vertical lift switchgear with 600, 1200 and 2000 amp., type FK-44B oil circuit breakers. All primary connections except instrument and relay transformers insulated for 15 kv. Relays and instruments mounted on swinging doors.

Boiler Auxiliary Bus Equipment—Sheet steel welded cubicles assembled by Philadelphia Elec. Co. using General Electric Co. FK-12, 300 amp., 15 kv. oil circut breakers which were available in stock.

Station Light and Power Transformer—Allis-Chalmers Mfg. Co. 7,500 kv-a., 13,800—2300 v. three phase inert gas equipped transformer.

Stub Bus Transformer—Allis-Chalmers Mfg. Co. 3750 kv-a., 14,500—2300 v. three phase, inert gas equipped transformer.

Copper Channel Bus and Generator Lead Runs—Anaconda Wire and Cable Co. 6 in. and 8 in.

Auxiliary Transformers—300 kv-a., 2300 to 230 v. single phase transformers connected two in open delta. Originally General Electric Co. 13,200 to 230 v., but rewound by American Elec. & Maint. Co., Springfield, Mass., for 2300 to 230 v.

Switchboards—230 v. a.c. and 250 v. d.c. contactor panels. Cutler-Hammer, Inc. Generator voltage regulator panel, Westinghouse Elec. & Mfg. Co. All other switchboards, Philadelphia Elec. Co.

Generator Oil Circuit Breakers—General Elec. Co. 5000 amp., 15 kv. FHK-330-32B.

Generator Reactors—General Elec. Co. 1833 kv-a. 5 per cent.

Generator Disconnect Switches—Electric Power Equip. Co. 5000 amp., 15 kv.

Cable

13,800 v. service: Paper and lead, Simplex Wire & Cable Co.; generator neutral, 15,000 v. Kerite, Kerite Insulated Wire & Cable Co.

2300 v. service: 6000 v. Kerite, Kerite Insulated Wire & Cable Co.; 6000 v. Okolite, The Okonite Co.; 7500 v. Rockbestos (Lead Covered), Rockbestos Prod. Corp.; 6000 v. varnished cambric, Simplex Wire & Cable Co.

230 v. a.c. and 250 v. d.c. service: Generator Excitation, 5000 v. varnished cambric, and 600 v. Anoroc, Simplex Wire & Cable Co.; Power and Control, 600 v. Kerite, Kerite I. W. & C. Co.; 600 v. Okolite, The Okonite Co., 600 v. Anoroc, Simplex Wire & Cable Co., 600 v. Rockbestos, Rockbestos Prod. Corp., 750 v. varnished cambric, General Elec. Co., 1500 v. Rockbestos (Lead Covered), Rockestos Prod. Co.

stant potential and the other generator supplies the armatures with variable potential. Varying the field of the variable potential generators changes the speed of all motors connected to the variable potential bus, which in turn regulates the fuel flow to the furnace.

Some of the switchboards required for the new installation have been furnished in light colors as a result of a number of experiments in lighting of control rooms, which indicated that the lighter finishes for switchboards contribute to better lighting and have a tendency to relieve eyestrain by reducing the contrast between switchboards and light walls and ceilings. Boiler control panels were painted a silver grey aluminum color, and the fuel preparation control panels were constructed of stainless steel in natural finish. As an experiment, swinging panels on the auxiliary starting cubicles were finished in light grey.

In the studies made to determine the expected duty for the 5000-amp. oil circuit breakers, it appeared from calculations of expected short circuit conditions and rate of recovery voltage rise across breaker contacts that this duty would be rather severe. Tests were made on one breaker in the field using a second breaker in its permanent position as a "back-up" breaker. The kv-a. duty of the breaker in the test was much less severe than calculated, but the tests did give assurance that the breaker should perform successfully in service at Richmond, particularly with respect to rate of recovery voltage rise.

The addition to Richmond was designed and constructed by United Engineers and Constructors, Inc., in conjunction with the engineers of Philadelphia Electric Co.

Dixence Valley Station Operates on World's Highest Head

By ROBERT CHESSEX

IN SPITE of the considerable development in the electrification of Switzerland, some important enterprises remain still to be carried out, and others to be completed. Among the latter may be included the construction of the power station of the Dixence Valley which has just been put into partial operation. It consists of a central high-pressure station yielding a head of 5740 ft., the highest in the world.

In the Valley des Dix, at the far end of the Hérémence Valley (one of the lateral valleys on the left bank of the Rhône, in the canton of Valais), at an altitude of 6550 ft., a large dam has been constructed and has been almost completed. It will measure about 1300 ft. on the summit, and will be 280 ft. high, with a base 230 ft. thick. When finished, it will form a solid mass, 523,200 cu. yd. of gneiss-coated concrete.

The necessary ballast for the undertaking was procured on the spot by steam-baggers, while the cement was brought up from Sion by telpherage, over a distance of 10.7 mi., as the crow flies, representing over 5600 ft. difference of level. The heavy material was brought up by lorries on a specially constructed road, and thence by a funicular, with a gradient, at its steepest, of 107 per cent, i.e., more than 45 deg. and a train-road of about 2785 ft. in length.

The lake formed by the dam, when completely filled, will have a capacity of 65,400,000 cu. yd. of water. At present it contains a certain quantity of water, as the power station was put into partial action last November.

From the lake, water is forced through a 7.5 mi. tunnel, which is hollowed out of rock, to the water castle where the dual water pipes lead to the power station at Chandoline near Sion, 5750 ft. below. Each of these pipes is made of steel tubing, smooth at the top and iron-bound below, i.e., covered with reinforcing hoops in order to resist the increasing pressure and avoid considerably increasing the thickness of the walls of the tubes themselves. The diameter of the interior of the tubes decreases from 57 to 39.4 in. and the total weight, together, is 14,800 t. The parts of each tube are welded together electrically, except where special forms are encountered.

The Chandoline power station contains five principal generating units of which one is a reserve, and one an auxiliary unit. At the present moment, three principal units and the auxiliary unit are in operation. Each group consists of one three-phase generator of 30,000 kw. capacity driven by two single-jet Pelton turbines of 21,250 hp. each, placed on either side of the generator on the same shaft. The principal units supply one system of 65 v. and another high power system of 130 v. through the intermediary of a booster.

The installation is constructed to yield 362 cu. ft. per second, giving a total power of 133,250 kw. to the terminals of the boosters.

Modern Methods of Checkmating CORROSION

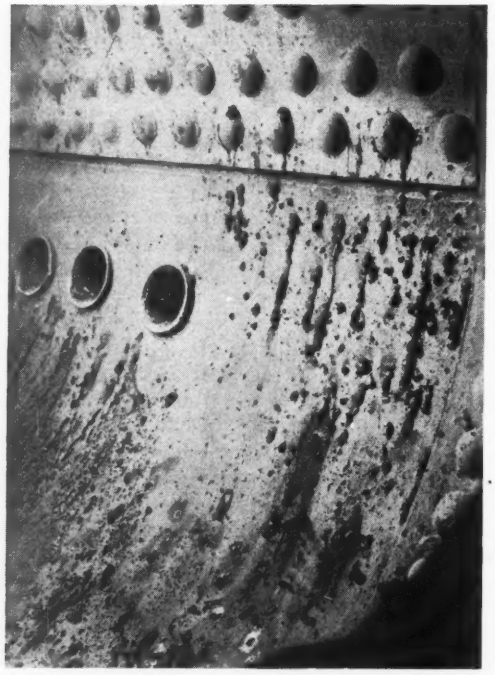


Fig. 1. Result of stand-by condition without provision in the water for maintenance of the protective film

One of Nature's most effective methods of transporting metals long distances is first to convert them to a liquid state. To preserve metals in solid form, scientists have delved into the fundamentals of this destructive process called corrosion and have devised positive control methods

By DR. R. E. HALL
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TO CHECKMATE corrosion, the circumstances leading to its occurrence must be understood. In this brief discussion, only the general case of metal in contact with water will be considered.

Fundamental Equilibrium

The fundamental relationship between metal and water of interest in this connection is the equilibrium which may be expressed thus:

(1) Metal (Solid) ⇄ Metal (Dissolved)

This equilibrium signifies that when a metal is placed in water, it dissolves to some extent, but in so doing establishes conditions such that dissolving action gradually ceases, finally becoming nil and remaining so, as long as the conditions established remain undisturbed. When that state of affairs is reached, a slight shift of conditions in one direction may result in further dissolving action, and a slight shift in the other direction may cause reversal of the dissolving action, and actual plating out of the dissolved metal on the solid metal surface. In other words, the equilibrium represents a balance for an established set of conditions. The amount of metal dissolved is dependent partly upon the specific metal, and partly upon the characteristics of the water. Of other factors influencing the equilibrium, that of potential differences occasioned by neighboring substances or physical variations within the metal itself occurs as frequently as any.

Thus, in pure water, sodium dissolves in large amount; magnesium in appreciable but smaller amount; iron and copper in still lesser quantity; and metals such as gold and platinum almost infinitesimally.

Acidity, or decrease in pH value of the water, shifts the equilibrium to the right, and more of the metal dissolves. Acidity may be derived from many sources as dissolved carbon dioxide, or hydrochloric, acetic, sulphuric, phosphoric, and many other acids, also all substances which lower the pH value such as sodium acid sulphate, ammonium chloride, zinc chloride, monosodium phosphate, etc.

Alkalinity, or increase in pH value of the water, shifts the equilibrium to the left, and less of the metal dissolves, except for the special case of amphoteric metals such as aluminum and zinc.

Velocity Factor of Corrosion

If the metal is in contact with a fixed quantity of pure or slightly acid or alkaline water (as in a closed vessel) the initial velocity of dissolving is relatively rapid, decreasing and finally becoming nil when equilibrium is reached. Increase in temperature hastens attainment of equilibrium in all cases, and in general favors reaction to the right. The velocity of dissolution is retarded by any inert coatings or films applied to or formed on the surface of the metal, to the extent that they interfere with free contact of metal and water. Coatings or films, however, which are not inert, may retard or accelerate the velocity according to their nature, and may further alter the fundamental equi-

librium condition. Conversely, any agency which is destructive of the protective films is favorable to speed in dissolving. Said agency may be chemical, having a dissolving action on protective films, or physical as illustrated by abrasive action, however gentle. Thus pH values, films or coatings, and temperature largely constitute the velocity factor of corrosion.

Protective Coatings or Films

The part played in our economic life by protective coatings and films is tremendous. Familiar examples of coatings mechanically applied are paints, varnishes, and lacquers of all kinds. Their function is to provide an impermeable barrier between the moisture of the air (oxygen also, but this is discussed later on) and the metal. The paints with lead, iron, chromium or zinc oxide base function also by reason of the basicity of these oxides in contact with water. A familiar example of chemically applying a coating is the Parkerizing of iron, wherein an iron phosphate coating provides the protection. Galvanizing of iron and chromium or nickel plating are other examples.

These applied coatings function with great success when the percentage of water is not too great, but for conditions approaching continuous immersion of the metal, oxide films of the metal itself, forming naturally and maintained by carefully controlled conditions in the water, provide more certain protection. An oxide of aluminum is the barrier which protects metallic aluminum from readily dissolving and corroding in the moisture of air, or when used as a utensil, or for other similar purposes. Likewise, oxides of chromium, copper, zinc or nickel form protective coverings on the surfaces of their respective metals. At times, a film of hydrogen may form on the metal surface, and be protective.

Treatment of water in contact with the metals can effect protection by film formation. Thus an alkaline water aids the formation of a protective film on iron, copper or nickel. Therefore, one of the essentials for the protection of iron immersed in water is an alkaline condition of the water. Sodium chromate dissolved in water is specifically effective in the formation of a protective film on iron, but not on copper. Sodium silicate, added to a hot water system, forms a protective silicate coating on the surface of the piping. Effectiveness of the sulphate—alkalinity ratios maintained in boiler waters to prevent caustic embrittlement rests upon formation of an impermeable solid coating of sodium sulphate on the metal surface, thus preventing its contact with and corrosion by the caustic water.

The effect of depriving the metal of an impermeable protective film is readily demonstrated. Perhaps as striking an illustration as any is furnished by aluminum. Protected by its oxide coating, and immersed in water, a plate of sheet aluminum gives no evidence of corrosion. Dipped in a dilute solution of mercuric salt, thus permitting some amalgamation to occur, and then withdrawn, its corrosion is immediate and the heat developed so great that the water clinging to its surfaces rapidly evaporates as steam. An alkaline water readily dissolves aluminum oxide as sodium aluminate, zinc oxide as sodium zincate, and tin oxide as sodium stannate, thus exposing the clean metal surface to the dissolving action of the alkaline water. Nickel and copper oxide films are not dissolved by an alkaline water and thus Monel metal, an alloy of them, is dependable therein. In an acid water, the oxide films dissolve, with different degrees of readiness to be sure, the chromium oxide film of high chromium steel being extremely resistant. The specific protection of sodium chromate to iron is less certain in a water of high chloride content, because the chloride impairs the stability and impermeability of the oxide film.

The Quantity Factor of Corrosion

If nothing interferes with establishment of the concentration of dissolved metal which constitutes the right hand member of the fundamental equilibrium, eventually equilibrium is attained, and further dissolution or corrosion is at a standstill during its continuance. Substances that react with the dissolved metal, thereby effecting decrease in its concentration, and preventing the establishment of equilibrium, serve to maintain unimpaired its velocity of dissolution, and therefore to cause continuing loss of the solid metal. They constitute the quantity factor of corrosion, as distinguished from pH value and inert protective coatings or films which are the major controlling factors of the velocity at which the metal will dissolve or corrode.

Examples of the Quantity Factor: Oxygen

Dissolved oxygen is the most common example. When dissolved oxygen meets dissolved iron which is in the ferrous or lower oxidized state, and relatively soluble, they combine to form ferric, or more highly oxidized iron oxide, whose solubility as ferric hydroxide is extremely small. Thus dissolved iron is removed from solution, and the fundamental equilibrium reaction (1) proceeds to the right in the effort to supply the deficiency of dissolved iron. The Laws of Henry and Dalton state that the amount of oxygen dissolved by water is proportional to the partial pressure of oxygen in the vapor or air in contact with the water. The equilibrium between gaseous and dissolved oxygen may be thus expressed:

(2) Oxygen (Gaseous) $\rightleftarrows$ Oxygen (Dissolved).

Thus, as combination of dissolved oxygen and iron occurs, the concentration of the former, as well as of the latter decreases. If the water is in contact with vapor or air containing gaseous oxygen, this supply serves to make up the deficiency of dissolved oxygen, the reaction proceeding to the right. Hence, dissolved oxygen and iron continue to combine, the departure

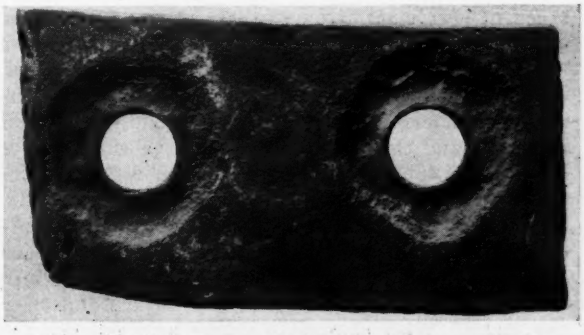

Fig. 2. Localized stress by staybolts was the reason for this corrosion

from their equilibrium values in solution causes the dissolution of more solid iron and gaseous oxygen, and the process we know as corrosion continues until the exhaustion of one or the other component, or until something happens to change conditions.

The velocity of the process will depend on the one hand on how rapidly dissolved iron is supplied, and this in turn depends on pH value of the water, or the permeability of films and coatings on the metal, or the relationship of electric potential between any point on the iron and neighboring points; on the other hand, on how rapidly dissolved oxygen is supplied which in turn depends on the partial pressure of oxygen in the vapor phase, quiescence of the water and the distance of the metal surface from the oxygen supply. Circulation or agitation of the water more quickly effects meeting of dissolved metal and oxygen

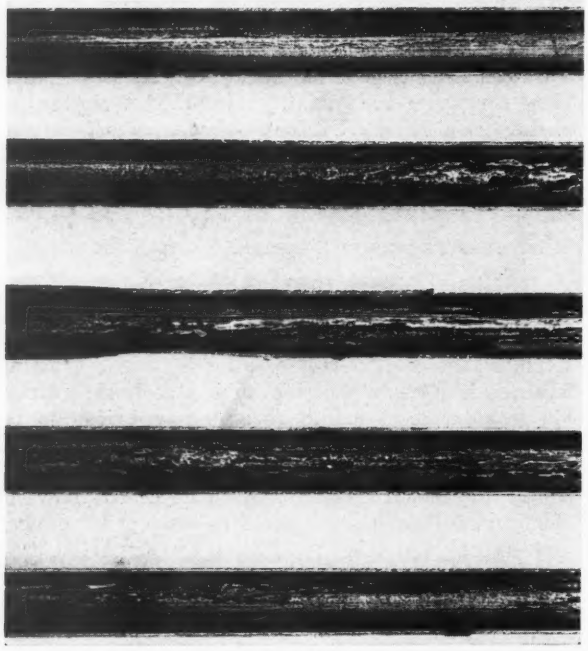

Fig. 3. There was no checkmating of corrosion of these condenser tubes

than their diffusion through quiescent water. Thus, condensation of dew drops whether on a saw or other iron surface left out over night, or on the surface of the steam space of a boiler in standby condition provides a generous supply and easy meeting of dissolved metal and of oxygen, and therefore assures speed of corrosion. Iron surfaces of the humidifying chamber in air conditioning processes are in like manner an apt target for severe corrosion. Alkalinity or higher pH values opposes readiness of dissolution of iron, rendering any oxide coating more impervious to water, and thus retards corrosion velocity; acidity aids dissolution, destroying any oxide film, and thus speeds up corrosion velocity.

Copper immersed in alkaline water suffers inappreciable corrosion, whether dissolved oxygen is present or not. The copper oxide film is stable and protective and there is very little tendency to dissolution of the metal. With change to dilute acid condition of the water, in the absence of dissolved oxygen or oxidizing conditions, there is still inappreciable dissolving; the oxide film dissolves, but a mere trace of metal dissolves before equilibrium occurs. With dissolved oxygen present, however, continued formation of copper oxide occurs, which readily dissolves in the acid water, is thus continuously removed, and the process of dissolution or corrosion steadily proceeds. Thus a strip of copper placed in oxygen-free water acidified with dilute sulphuric acid, gives no evidence of corroding action. When, however, air is bubbled through the water, dissolution or corrosion of the copper readily occurs. Nickel, and its alloy with copper, Monel metal, correspond quite closely to copper in these reactions.

The oxide films of zinc and aluminum dissolve in acidified water, whereupon, with or without dissolved oxygen present, further dissolution of the metals occurs.

Particularly in alkaline or neutral water, corrosion by sulphide occurs. The mechanism is quite plain—under these conditions, the sulphides of iron, copper and nickel, and of zinc in neutral or only slightly alkaline water, are among the most insoluble substances known. Thus they remove the dissolved or right hand member of the fundamental equilibrium between metal and water, so that continuing dissolution of the metal must occur, and eventually represent severe corrosive loss.

Complex Radicals

Aluminum, deprived of its protective oxide coating and in contact with water, is more strongly reactive to the right in the fundamental equilibrium (1) than iron or zinc. An alkaline water dissolves the oxide coating, but more than this, very completely removes the dissolved aluminum from effectiveness in the equilibrium, thus paving the way for continued speed in dissolution or corrosion of the metal. This result is effected not by precipitation of an insoluble compound of the metal, but by its sequestration in soluble complex radical form as sodium aluminate. In the soluble aluminate radical (AlO_2), the aluminum is very completely removed from the water,—just as effectively as iron is removed from its equilibrium by precipitation as insoluble ferric hydroxide. Thus aluminum, in contact with an alkaline water, corrodes steadily, and dissolved oxygen has no material effect one way or the other.

Likewise, an alkaline water dissolves the oxide coating of zinc, and as the metal attempts to establish its equilibrium by dissolving, the dissolved component is removed and sequestered in the soluble complex zincate radical (ZnO_2). Thus, as in all cases where the protective oxide coating is destroyed, and the dissolved component is removed as fast as formed, corrosion proceeds rapidly, surely, and continuously, with or without dissolved oxygen.

In like manner, the formation by an alkaline water of the soluble complex stannate radical (SnO_2) of tin, paves the way for corrosion of this metal. Thus, strongly alkaline boiler waters quite frequently accomplish the dissolution or corrosion of fusible boiler plugs.

In the presence of caustic alkalinity, the oxide film of copper is stable; but in the presence of ammonia it dissolves, the copper reacting with the ammonia to

form the soluble complex cupri-ammonium radical $[Cu(NH_3)_4]$ which sequesters the copper and thus very completely removes it from solution. In the fundamental equilibrium (1) of copper and water, the right hand member is of very slight value, and effectiveness of ammonia in causing dissolution of the metal is thus minimized. In the presence of dissolved oxygen, however, which will continue to form the readily dissolved oxide film, corrosion proceeds continuously. Nickel, likewise, forms the complex nickelous ammonium radical $[Ni(NH_3)_4]$.

Alloys such as the brasses, bronzes, Monel metal, etc., are sure to suffer when subjected to some of the conditions just depicted.

Means of Checking Corrosion

The most effective checkmate is to make the right hand member of the fundamental equilibrium zero or as nearly so as possible. This means an impermeable and permanent film or coating on the surface of the metal which must be a total barrier to its contact with water. No commercially available substance provides this permanence of film under all conditions. Stainless steel in contact with oxidizing-acid or alkaline water, with dissolved oxygen present or absent, is a near approach to that condition when the ratio of chromium to iron is not less than 1 atom of the former to 8 of the latter. For some different sets of conditions, the copper, nickel, zinc and aluminum alloys are excellently effective.

The protection in contact with water of commonly used metals such as iron or steel, copper, nickel, zinc, or alloys such as the brasses, bronzes or Monel metal can be attained only by establishing those conditions in the water which are not deleterious to their protective oxide films. Thus for the protection of iron or steel, alkalinity and absence of dissolved oxygen in the contacting water are essential. The presence of ammonia is not harmful. For copper, nickel and Monel metal, an alkaline contacting water containing dissolved oxygen is satisfactory, but ammonia is destructive of the oxide film under these conditions, and its presence in the water must be carefully avoided. Since an alkaline water dissolves the protective oxide film of zinc, it readily dezincifies and thereby destroys the usefulness of brass. Thus in valves which come in contact with alkaline boiler water, brass seats are short lived.

In the light of these various considerations, which have been all too briefly touched on, the logical procedure in checkmating corrosion would seem to be to decide on various conditions in the contacting water which can be economically maintained, list those metals suitable for the purpose in hand whose surface-protecting films resist attack under the conditions to be maintained in the water, and finally make choice of metal and conditions of water which represent maximum resistance to attack on the protective surface film of the metal. Certainly this procedure is more economical and satisfactory than to choose a metal haphazardly, and then in order to avoid corrosion be compelled to move heaven and earth in the effort to establish in the contacting water conditions which are not inimical to the protective oxide film of the metal.

Recent Lightning Investigations

THE AMOUNT OF CURRENT in a flash of lightning ranges from approximately 4000 to 220,000 amp. and practically always come from negatively charged clouds, it was reported by C. M. Foust and J. T. Henderson, General Electric engineers, in a paper presented at the summer convention of the American Institute of Electrical Engineers, at Ithaca, N. Y., June 25. In thousands of places, widespread through numerous countries, magnetic records of the current in flashes of lightning are being obtained, using a new surge-crest ammeter to measure and interpret the effects of the lightning on "magnetic links" mounted close to transmission towers. The information thus gained, coupled with lightning voltage measurements as obtained with the oscillograph, or millionth-of-a-second camera, and with studies such as those made in the high voltage and high current laboratories where man-made strokes of 10,000,000 v. lightning are employed, serves electrical engineers in many ways. Knowledge is gained about the nature and strength of lightning; methods of protecting electric generating and transmitting equipment are revealed; and studies in the development of devices to lessen electric service interruptions are aided.

The method of procedure in the field is extremely simple. Small pieces of magnetic material, called magnetic links, are mounted on brackets and installed within a few inches of one or more legs of the transmission tower. Several thousand such links are in use along various transmission lines.

Voltage Determined from Magnetized Links

In passing through the transmission tower a stroke of lightning magnetizes the link in proportion to the highest value of current in the lightning bolt. Line patrolmen, working under the research staffs of the power companies, make regular examinations of the links and upon discovering, by means of simple instruments, that a link has been magnetized, remove it and turn it over to the engineers.

When placed in the magnetic measuring instrument, known as a surge-crest ammeter, the magnetized links cause the pointer of the ammeter to indicate on a scale a measure of the highest value of current in the lightning bolt.

Two of the magnetic links are installed in each leg of the tower, at definite distances from the tower itself. Engineers have compiled tables so that they can quickly tell, from the surge-crest ammeter readings for each pair of links, just what kind of a lightning stroke was recorded. The interpreted readings, for instance, show to what extent the stroke was oscillatory, and how many thousands of amperes flowed through the transmission tower. Combining the reading of links of different legs of the same tower, and of different towers, it is possible to compute the maximum strength of the lightning stroke.

It has been established that roughly seventy-five per cent of all interruptions to electric service are caused by lightning.

Combustion Control

Part VII. Ruggles-Klingemann Mfg. Co. Step Action Hydraulic Pressure Regulators as Used for Boiler Control. Constant and Variable Step Compensators and Undervoltage Release for Motor Protection

STEAM AND FURNACE PRESSURE regulators are sensitive in operation and ideally suited to meet the varied needs of combustion control applications. Due to local requirements of equipment and operating conditions, it is difficult, if not impossible, to standardize boiler controls, but, the flexibility of commercial regulator equipment is such that any need can be met. In this series of articles a definite effort will be made to show the application of control equipment to a diversified list of plants and fuels, but the use of a regulator in these examples should not be considered as limiting its application to that particular arrangement.

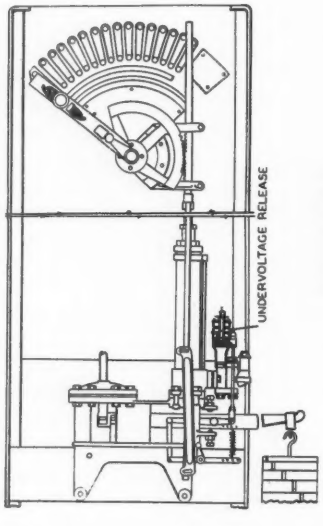

Fig. 2. Steam pressure regulator operating dial switch on a motor drive. The undervoltage release prevents the motor being left across the line in case of a power interruption

Figure 1 shows the application of Ruggles-Klingemann step action regulators to the control of one or more gas or oil fired boilers. It will be noticed that the furnace pressure regulator and steam pressure regulator are interlocked. This is to eliminate the possibilities of the uptake damper being closed while fuel and air are being fed to the furnace. Normally this damper, which is counter-weighted and tends to close, is under the control of the furnace pressure regulator which is free to operate the damper so as to maintain a uniform furnace pressure. Should this regulator fail

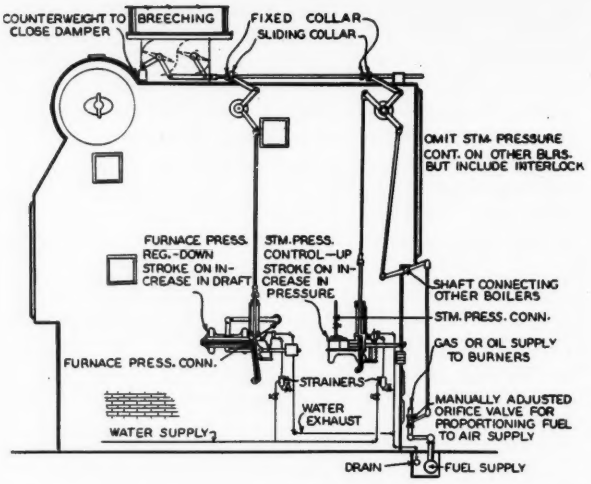
COUNTERWEIGHT TO CLOSE DAMPER
BREECHING
FIXED COLLAR
SLIDING COLLAR
OMIT STM. PRESSURE CONT. ON OTHER BLRS. BUT INCLUDE INTERLOCK
FURNACE PRESS. REG.-DOWN STROKE ON INCREASE IN DRAFT
STM. PRESS. CONTROL—UP STROKE ON INCREASE IN PRESSURE
SHAFT CONNECTING OTHER BOILERS
STM. PRESS. CONN.
GAS OR OIL SUPPLY TO BURNERS
FURNACE PRESS. CONN.
STRAINERS
MANUALLY ADJUSTED ORIFICE VALVE FOR PROPORTIONING FUEL TO AIR SUPPLY
WATER EXHAUST
WATER SUPPLY
DRAIN
FUEL SUPPLY

Fig. 1. Ruggles-Klingemann controls with a mechanical overriding interlock as installed on a gas or oil fired boiler

or be inoperative for any reason, the steam pressure regulator would assume control through the interlock and regulate both the damper and the fuel supply.

In normal operation, however, the steam pressure regulator controls the fuel feed and air supply by means of the parallel operation of valves which may be manually adjusted to give desired air-fuel ratio. The fuel valve used is of the adjustable chronometer type which is also used for the speed control of steam driven fans and stokers. It consists of a Corliss type of rotating valve operated through a given angular movement by the regulator. The ports are rectangular and adjustable axially by means of a handwheel so that the port opening depends upon two movements: the automatic angular rotation of the valve by the regulator and the correlation of the valve and port which is adjusted by hand. In the case of a forced draft stoker fired boiler the fuel valve shown in Fig. 1 would be replaced by a damper or perhaps by a steam valve in the line supplying the fan or stoker engine.

Application of control to a single boiler is comparatively simple. There are, however, usually several boilers which may well be controlled by a single steam pressure regulator by means of a line shaft as shown by Fig. 1. In this way the boilers are all operated in parallel and increases and decreases in steam load will be automatically divided between them. The furnace pressure will, however, be maintained in each boiler by individual furnace pressure regulators which would be installed with the interlock as shown by Fig. 1.

Details of the steam pressure regulator and its operation are given by Fig. 3. The furnace pressure regulator is fundamentally the same but is equipped with a larger diaphragm as shown by the installation drawing, Fig. 1. These regulators are of the "step action" type and the piston travels the length of its stroke usually 10 in. in 10 definite and uniform steps or positions. This means that the regulator does not respond to small pressure fluctuations but changes damper and fuel settings only after pressure changes of sufficient value to indicate a permanent change in load. The manufacturer claims that the step action principle avoids unnecessary changes in furnace con-

ditions and therefore effects economies closely approaching base load operation.

Normal pressure for which the regulator is set is determined by the weight loading at the end of the beam. The pressure variations from this valve, necessary to cause a full piston stroke, is determined by the slope of the compensator, the greater the slope, or angle with the vertical the greater the pressure variation necessary to change the damper from fully opened to fully closed position.

When regulators are used to control auxiliaries by means of valves in the steam lines the flow through the valves may be changed by means of special ports to give the desired characteristics to go with the uniform step action of the regulator. With dampers, however, the problem is not so simple. When nearly closed a small angular change of the damper makes considerable difference in draft but when nearly open the same angular change affects the draft but little.

In order to compensate for this so that the gases may flow in steps proportional to equal increments of steam flow, a variable step compensator shown at the right of Fig. 3 was developed. By means of this device uniform steps in steam pressure are made to produce uniform steps in draft and not uniform steps of the piston travel. The compensator is adjusted by means of the necessary draft indicating instruments while the boiler is in operation.

As normally installed the damper is open when the piston is at the bottom of its stroke and any increase in steam pressure causes the piston to move up and close the damper. At first the movement of the damper affects the draft but little and a considerable change must be made to get the desired effect. Therefore, the first part of the compensator bar (the top) should be curved but slightly. As the damper closes the change becomes more effective and the curvature should increase as shown in the drawing. Adjustments are made by changing the check nuts to increase the angularity of the blade and at the same time moving the steps closer together on the vertical bars by means of clamp screws.

When motor driven auxiliaries are used, the regulator may be adjusted to the operation of a dial switch as shown by Fig. 2. Regulators for this service are equipped with a duplex pilot valve under the control of an under-voltage release. This is shown in heavy black in the drawing. In normal operation the switch is controlled from pressure acting on the diaphragm but on a failure of the power supply, the solenoid is de-energized and the plunger connected to the second pilot valve, operates the piston and starter to cut the full resistance in the motor circuit. The motor is thus positively protected against the danger of being left directly across the line.

These regulators having definite predetermined cut-off points are well adapted to motor control as they can be provided with the required number of step positions corresponding to the control points on the starter. The controller arm is also moved quickly from one position to another and definitely stepped in position on the proper contact. The same regulator can, of course, be used to control stoker speed by making connection to the top of the gear rack and operating the throttling valve, rheostat or variable speed device as the case may be. In the case of pulverized fuel control of the fuel is usually made through the feeder.

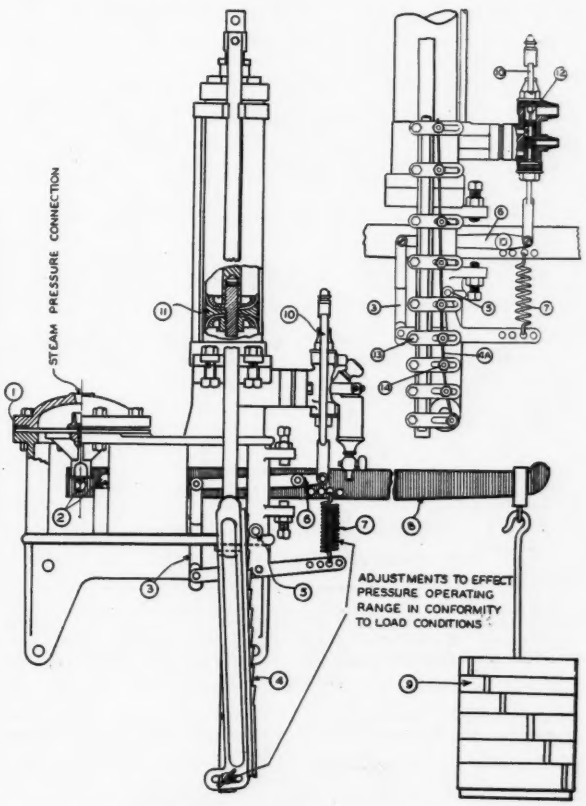

Fig. 3. Step action regulator and, on the right, detail of pilot valve and variable step compensator

Steam pressure admitted to the top of diaphragm 1 is balanced by the weights 9 around the pivots 2. The heavier the weight the higher the normal pressure setting of the regulator. An increase in steam pressure lifts the beam 8, the yoke 10 and the pilot valve 12 (shown sectionalized in the small drawing at the right). When the pilot valve is displaced upward water pressure is admitted to the bottom of the water passages operating cylinder and the top is opened to the drain so the piston 11 moves upward carrying with it the step wedge 4. Due to the step design of the wedge there is practically no movement of the compensator levers until the roller 5 suddenly strikes the first notch. This movement of the cotter is transmitted through arms 3 and 6 and moves the pilot valve down to neutral position, increases the tension in spring 7 to change the pressure setting of the regulator and locks the piston in position, until another pressure change equal to the next step in pressure takes place. On a decrease in steam pressure the pilot valve is moved downward and the compensator operates to again move it up to the neutral position.

The pressure change per step is changed by adjusting the slope of the wedge 4. The farther the lower end of the wedge is swung to the right the greater the pressure change per step. Additional adjustment is provided by means of the spring 7. Changing this spring to give a longer arm position has the same effect on the pressure change per step as increasing the angularity of the wedge. The compensator wedge and mechanism at the left gives uniform steps in piston travel. The detail at the right shows a variable step compensator which operates exactly the same as the other except that the compensator wedge 4 is replaced by an adjustable blade 4A. Adjustments are made by means of shifting the blade by loosening check nuts 14 and shifting the steps vertically by loosening clamp screws 13.

Recent Developments *of the* INDUSTRIAL TURBINE

Development of Radial Flow Turbines in Germany Aimed Particularly at Industrial Field Outlined in Siemens Review

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DEVELOPMENT of high-pressure steam plants has rendered it necessary to devise turbine designs for dealing with high-pressure steam which are also capable of ensuring the maximum economy in the use of the steam. The development of the modern industrial turbine is thus in general characterized by the endeavor to improve the efficiency of the high-pressure stages for increasingly high pressures.

Prior to the advent of the high-pressure movement (1923) the chief means of reducing high steam pressures was the Curtis wheel. A more efficient machine is obtained if instead of using a single Curtis wheel with two or three rows of blading, the heat drop is spread over a number of pressure stages, usually three. Such designs are also simple.

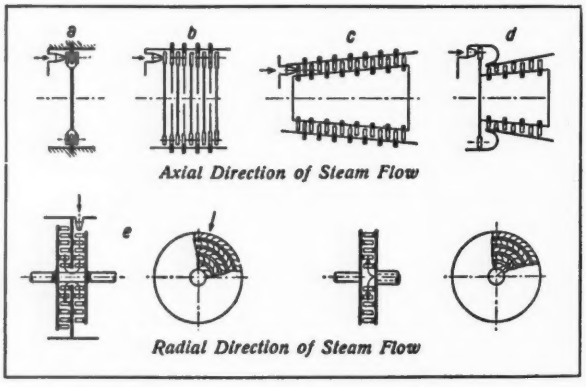


Fig. 1. Fundamental Types of Turbines. a, velocity. b, impulse. c, reaction. d, combined impulse-reaction. e, simple radial Siemens-Schuckert combined impulse reaction. f, double motion reaction (Ljungstrom)

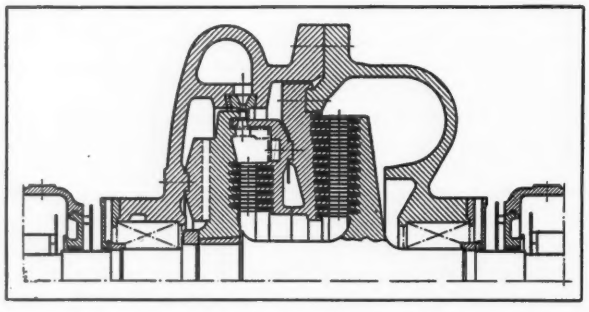


Fig. 2. Back-pressure Radial Turbine, 1500 kw. 5000 r.p.m. Siemens-Schuckert Type (Capable of conversion for higher pressures).

The efficiency of a turbine stage depends mainly on the speed ratio of the peripheral speed to the steam velocity or for a number of stages on the so-called Parson's number. Next in order of importance is the blade clearance and the amount of play in the radial labyrinth. In the third place, the efficiency at low values of the load is influenced by such factors as the volume of steam, the initial pressure, the final pressure and the adiabatic drop. Further, an increase in the steam pressure must bear a definite relationship to the volume of steam passing through the turbine if a certain value of the efficiency is to be attained. If the pressure exceeds the predetermined value, the efficiency will fall off rapidly, so that the increase of the pressure results in no economic advantage. A safe rule of thumb, which is also demonstrably correct in theory, is that the steam pressure in atmospheres should be approximately double the steam flow measured in tons per hour.

For larger values of the pressure drop a larger number of stages becomes necessary, the number increasing inversely as the volume of steam, i.e., the higher the pressure. Various types of turbines are shown diagrammatically by Fig. 1. Certain disadvantages of the axial blading led this company to the adoption of the radial direction of the steam flow.

Realizing the importance of this problem from the outset, Siemens-Schuckert turned their attention to the evolution of designs which permitted of the best possible utilization of the pressure drop at small outputs. Turbines of this type occur either as separate back-pressure units or as the high-pressure cylinders of bleeder turbines. In the design evolved the blading is arranged radially in concentric rings, this design possessing a high degree of thermal flexibility. One or two rotors are used, depending on the steam conditions.

Where the heat drop is small or where the turbine is not required to work with the maximum attainable efficiency, one wheel is used and is provided with either throttle or nozzle governing. The live steam usually flows from the center outwards, so that there is no necessity to use a high-pressure steam gland. These

turbines are characterized by their simple design and short length. The blading is also very easy of access, it only being necessary to remove one single cover. The disc which carries the blading is usually arranged overhung on the shaft.

The first turbine of this type supplied by Siemens-Schuckert in 1929 has overhung wheels which are mounted on either side of a central generator. The use of two discs with a definite number of blade rings was necessary in order to attain the desired efficiency on the basis of a given pressure drop without recourse to gearing.

High Efficiency

In the second basic type of simple radial turbine of Siemens-Schuckert design two impeller discs are used carrying concentrically arranged blading. Such turbines are employed chiefly for dealing with larger pressure drops and where high efficiency is desired. In this case it is customary to use nozzle regulation which distributes the steam to groups of nozzles feeding a velocity or Curtis wheel arranged in front of the radial stages as in Fig. 2.

Twin-wheel turbines are usually designed for the so-called U-flow arrangement of the steam, i.e., the steam enters the first set of blading from the outside and flows inwards, the direction being reversed in the second set of blading. By this arrangement and by the arrangement of equalizing labyrinths, perfect balance of the steam pressures is obtained under all load conditions, and the rotor is subjected to practically no axial thrust. Depending on the number of stages, the turbine can be built for any desired efficiency, up to the maximum obtainable.

The blading, Fig. 3, is the result of a new process of manufacture. The runner blades are fitted to the discs in concentric rings, whilst the guide blades are fitted to special carriers. Special attention has been paid to insure uniform expansion. By suitable choice of the pitch diameters and angular settings the ratio of the blade lengths has been maintained practically constant over the whole range of expansion, which has a very favorable effect on the steam flow. The design is specially suitable for operation at very high temperatures, and it is distinguished for the short time in which it enables the turbine to run up to speed.

Extraction

The turbines can be provided with tappings for extracted steam, these being either with or without governor control according to requirements. Overload tappings can, of course, also be provided if desired. As already explained, the foregoing designs can also be used for the high-pressure stages of condensing bleeder turbines. Again, the advantages of nozzle regulation are manifest, and the space between the two impellers can be used for a connection for live or bleed steam with a low pressure cylinder of the usual type with axial blading, since it operates at low pressures and temperatures. Depending on the size and duty of the turbine, it may be necessary to provide the low pressure cylinder with nozzle regulation, i.e., a Curtis wheel with adjacent drum part,

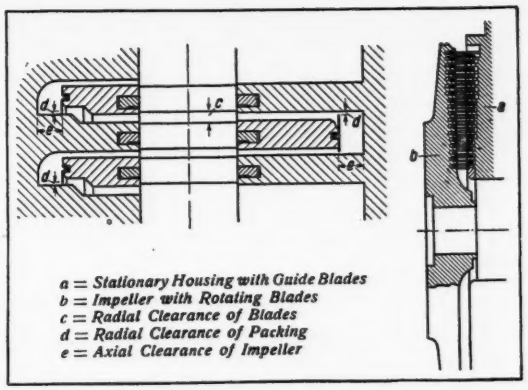

a = Stationary Housing with Guide Blades
b = Impeller with Rotating Blades
c = Radial Clearance of Blades
d = Radial Clearance of Packing
e = Axial Clearance of Impeller

Fig. 3. Blade Clearances and Diagram of Blading of Back Pressure Radial Turbine, Siemens-Schuckert Type.

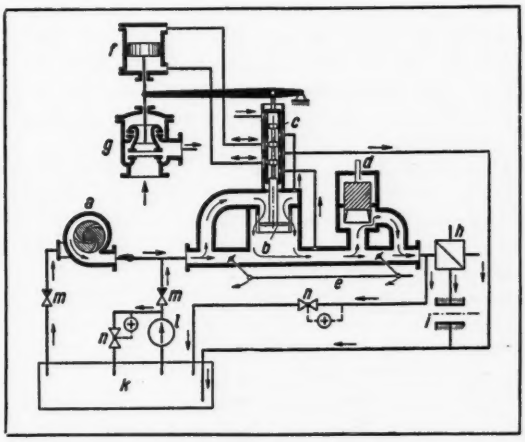


Fig. 4. General Arrangement of Hydraulic Governor Gear of a Steam Turbine, Siemens-Schuckert Type.

a, centrifugal pump on turbine shaft. b, floating piston with slide valve. c, return sleeves. d, automatic auxiliary valve. e, speed adjustment. f, servomotor. g, control valve. h, oil cooler. i, turbine bearing. k, oil tank. l, auxiliary oil pump. m, non-return valve. n, overflow valve.

which in conjunction with reaction blading insures good utilization of the low pressure steam.

For turbines of this type a new type of oil-hydraulic governor, Fig. 4, is used, which works on the principle of volumetric change at constant pressure. Two centrifugal pumps are fitted on the front extension of the turbine shaft, one of which supplies the oil for the governor gear, whilst the other maintains the circulation of the lubricating oil and provides the oil for the auxiliary motor. This arrangement renders superfluous the customary worm gears and gear-wheel pumps, also a large number of mechanical parts associated with the centrifugal governor gear. The new governor gear is exceedingly sensitive and rapid in its action, and is so designed that the turbine can only be run provided the oil supply is adequate.

For starting up and when stopping, a steam-driven auxiliary oil pump comes into action. As in the case of other designs, the turbine is automatically shut down in the case of the speed exceeding the safe limit by closing of the main valve and the nozzle valves.

Diesel *and* Gas Engines *in the* Oil Fields

Selection and Operation of Engines for This Service Outlined to the Oil and Gas Section of the A.S.M.E.

By GLENVER McCONNELL
Shell Petroleum Corp.

IT WILL not suffice to say that we have 10 or more selective styles of gas and oil engines for field usage, classified according to principle of design and fuel ignition. Nor is it important that we can say there are 30 or more characterized types according to operating speeds and fuel ignition.

Broadly speaking, all internal combustion engines may be grouped into two classes, viz., slow speed engines which work at 140 to 240 r.p.m., and high speed engines which work at speeds from 400 to 1500 r.p.m. (mostly 400 to 900).

Selection is determined by deciding first of all whether or not we choose to use a single speed reduction in the connection to the driven crank unit of the rig machine or to employ a double or triple reduction.

Slow speed engines are exemplified by the present oil field types. They are horizontal and, except for high power demands, have but one cylinder. They are made to run on gas, Diesel or crude oil fuel. All new types are convertible at a minimum of expense from one fuel to another. The convertible types are practically all two-cycle.

Perhaps 75 per cent of all engines used in the field today are the single cylinder horizontal type, either two or four-cycle. Such engines are too well known to be considered here at length mechanically. While two-cycle types have practically replaced a former demand for four-cycle horizontal engines in the Mid-Continent, the four-stroke cycle idea is not out of the picture. Recent development on the Continent has resulted in excellent tests and service reports on an improved single cylinder four-cycle engine of high speed and light weight, claimed to operate a steady load at 500 to 600 r.p.m. and capable of intermittent service at higher speeds.

Main improvements in oil field engines appear to consist in better crank shaft-flywheel balancing, use of alloy cast-iron cylinder and pistons honed to greater accuracy, improved heads, valves, bearings and lubricating systems. All vital working parts are now fully enclosed. Higher sustained operating pressures are the rule and surprising results with compression ignition of fuel are obtained. While it is known that pressure lubrication to journal, crank pin and cross-head pin bearings can be successfully used to reduce wear at high speeds, general application has not appeared. Roller bearings are quite successful for journals.

In the compression injection oil engines remarkable results are obtained. The popularity of these engines is increasing beyond that ever before attained. It has become possible to operate the latest designs of oil field engines on crude oil of 40-50 deg. A.P.I. and with high sulphur content. Over-zealous application of compression ignition engines to operate on such crude fuel leads some of us to believe it will result later in headaches, similar to what has followed too often the attempts to operate higher speed vertical engines of the compression injection type on crude.

Time will not permit a discussion of the relative merits of crude oil and specification Diesel oil, obtainable at low prices. But, a calculation will show that in many cases oil operators are kidding themselves into believing there is economy in using crude obtained directly from the wells. The actual cost may be higher in the long run. It is recognized that combustion with crude is incomplete and more fuel is required, as much as 50 per cent. This results in plugging of transfer ports, dirt in nozzles, needle abrasion, rapid pump plunger wear and a higher down time and labor expense for maintenance than with clean, refined fuel.

High Speed Engines

Installation of horizontal power units complete with only a cut-off clutch in the driving connection to a two-speed pumping rig machine and including water cooling and fuel connections will vary between $75 and $80 per operable connected horsepower suitable for long life and economy if gas fuel is used. Compression ignition oil engines will cost installed in a similar manner $85 to $100 per horsepower for the most selectable size for low cost well operation. These figures include also the cost of concrete and housing but not the driven machinery. Frequently the cost runs much higher, being dependent upon the type of driven machinery selected.

Maintenance cost will vary, dependent upon work performed, character of cooling water, fuel, lubricant and general features of design. Unfortunately for this class of engines, replacement parts are a bit expensive.

Double reduction pumping machines offer an excellent opportunity for more compact, higher speed engines such as multicylinder vertical units. This type of power unit may be easily transported completely assembled with enclosed cooling system, starter, clutch,

water pump, fuel regulator and outboard bearing, if necessary. The types most commonly known employ the four-stroke cycle principle, although we may expect considerable popularity with the two-stroke cycle using half as many cylinders. Two-cylinder, two-cycle engines will compete strongly with four-cylinder, four-cycle. How extensively is yet to be witnessed.

Now the question arises as to the practicability of high speed engines, and how high the appropriate operating speed. On the settlement of this question to a large extent depends their success or failure in competition with the time-honored, slow duty, horizontal engines, made especially for oil field application. Viewpoints may differ a bit, but it is reasonable to suppose that if, for instance, a four-cylinder, four-stroke cycle, vertical engine, of proven worth in other industries, can be selected of the same horsepower range as we require of the single cylinder engine, on the same fuel, with comparable piston speeds, lubrication efficiency, bearing areas, valve action and fuel injection features, of likely much higher precision in dynamic balancing and perfection of working parts, that there should be no risk whatsoever in the attainment of equal longevity under the same working load.

Operating History

Comparable longevity may be a bit doubtful, but the factor of obsolescence is not certain to cause any higher rate of depreciation for the heavy duty multi-cylinder as compared with the horizontal. We may find that operating histories of these two types covering parallel working conditions will reveal that the modern, "stripped" pumping mechanism requires no highly special design of engine for oil field usage. It is true that this is not according to what has already occurred.

What has occurred has been due to the allurement of low prices for automotive type engines, arranged and sold as power units, of low torque, high speed, cheap design and construction. Very familiar are the advertised tests and performance charts to those of us who must decide. Yet we feel there should be more field studies made by the designers of these engines before performance can be remotely estimated. Hence the oil industry, with shying skepticism, will not readily attempt widespread field application of high speed engines without more results of assiduous observation and planning.

A little walking before running is the attitude of the field engineers. So it now appears that for individual well pumping we should start applying the high speed engine to continuous duty with the piston speed travel of 600-700 ft. per min. We will observe manifold temperatures, cooling systems and the functioning of automatic devices which are necessary. We will know how to have lubricating systems that function for long periods, using not too special a grade of oil. It is already known that cooling water circulating system can generally be much improved, and no foundryman's inspection prior to assembly will be sufficient. Field water is generally bad. Finally, it is likely that all high speed engines will have to be equipped with automatic cut-offs for maximum temperature and minimum oil pressure limits to safeguard the installation.

From a viewpoint of comparable investment expense for installation in place ready to run, it is interesting to discover that there is practically no difference in final cost for the full Diesel, self-starting vertical four-cycle engines of the sizes required for pumping any present depth wells over the cost of lower compression crude oil burning, slow speed engines, provided piston speeds and reserve horsepower are practically the same.

Spark ignition engines, however, show up differently, and we find it possible to install "production" vertical engines at a saving of 25 to 30 per cent less than single cylinder horizontals. Any attempts to save more by selecting automotive types of higher speed point to a grave possibility of high maintenance and frequent replacements.

Maximum torque characteristics of such engines should be from 300 ft.-lb. of 600 or more compared to a range from 800 to 1600 for slow speed, single cylinder engines. It may be found, however, as with electric motors, that for single duty requirements even lower torques are sufficient for many individual well units.

A word or two about enclosed cooling systems is worth some consideration at this juncture. With high speed engines it would be folly to do without enclosed circulating systems. It is admitted to be much superior for any type of internal combustion engine to the open tank, open evaporating system, so long used for oil field engines. Certainly the user needs to look into the high cost which results from deposition within the water jackets of highly concentrated mineral salts from open concentrating tanks. The performance of oil field engines would be measurably improved if the open cooling system could be superseded by something better.

Water Circulating and Cooling Systems

We use gas engines because we wish to make use of free or cheap fuel for power. It is the custom to run engines on crude oil if gas is not available. More engines will likely be seen installed to run on distillates or on Diesel fuel. For these conditions, there are many engines. The slow speed types will serve, with some added expense for change-over parts, to run on gas, crude oil or Diesel oil. Spark injection, vertical high speed units will run on gas, gasoline, crude or Diesel oil of perhaps the widest range. The compression ignition or Diesel high speed units are not so generally convertible to gas engines. It is about as cheap to move out the Diesel when it is to be replaced with a high speed gas engine, especially since changes from one fuel to another are rather infrequent and the installation and transport costs almost negligible. The economic factor of available fuel appears to be just as advantageous with high speed as with low speed engines.

Therefore it behooves the users and makers of engines contemplated for service of individual well pumping to exchange viewpoints and to watch economic trends in well drilling, producing and equipment practice. The writer has purposely omitted much that can be said with the sole desire of pointing out how new plans of mechanizing individual well units for good operation introduce greater opportunities for all types of internal combustion engines.

Adequate Supervision of Boiler Room Improves ECONOMY

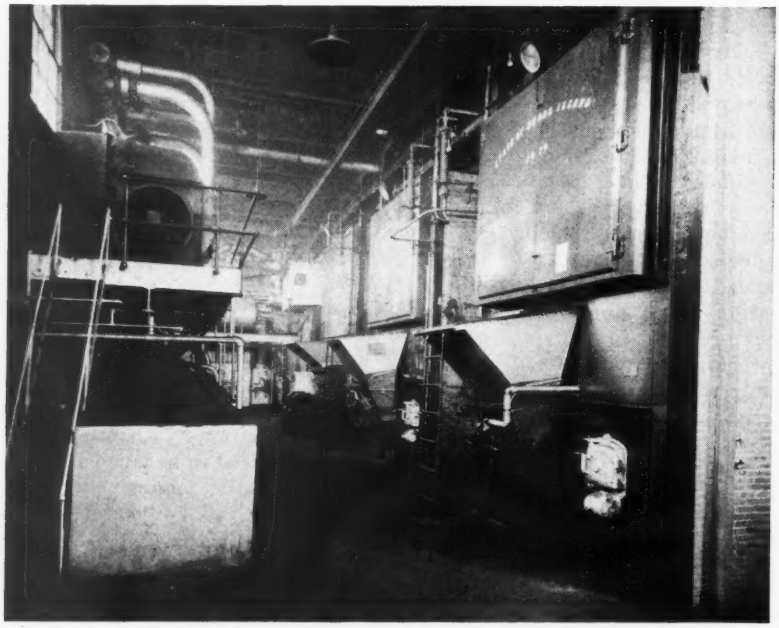


Fig. 1. General view of the boiler room, central power plant, Howard, R. I.

Definite Knowledge of Conditions Necessary for Operation. Methods of Obtaining High Efficiencies Outlined to N.A.P.E.

By

CHARLES E. BLAIS*

GENERATION of steam today requires the services of keen qualified engineers who are familiar with the fundamentals of unit design and specifically trained in the A. B. C. of combustion. To produce steam economically it is necessary to bring order out of chaos which sometimes exist in certain power plants as good judgment relating to operation often offsets to a large degree the lack of modern refinements.

Successful generation of low cost steam depends on six factors: Boiler installation properly designed for a specific job; sufficient draft for predetermined rates of operation; clean boiler and furnace accessories properly calibrated for coördination under varying load conditions; a good water supply, treated if necessary, for feedwater purposes; proper type of fuel best adapted for the boiler installation; the human element.

If it is difficult to engage the services of professional chemists to submit reports on the fuel proposed or used, or on the available water supply, it is suggested that a great effort be made to induce the employer to allot a very small amount of money for the purpose of purchasing cheap but practical items to provide a means of making a chemical analysis of the feedwater to determine the treatment, the extent of boiler treatment, if such treatment is necessary, and for the testing of coal.

Items of equipment (one each) for making a proximate analysis of water are: rigid stand for burette support; 50 c.c. burette, graduated in 1/10 c.c.; 200 c.c. measuring flask; 100 c.c. measuring flask; 50 c.c. porcelain dish; 22 oz. porcelain dish; small funnel for burette; glass funnel approximately 4 in. diam.; glass stirring rod; round copper receptacle for water bath; package of filter paper; 6 oz. concentrated solution methyl orange; one litre fifth normal standardized solution hydrochloric acid; one litre fifth normal standardized solution sodium carbonate; 6 oz. alcoholic solution phenol-phthalein. These items may be procured for approximately $15.00.

The following items of equipment (one each except where noted), are required for making a proximate analysis of coal: Bunsen burner; iron ring supporting stand; porcelain crucible with cover having a capacity of 15 c.c.; chemist balance, sensitive to one milligram; desicator for sulphuric acid; drying oven; one hundred mesh sieve; small mortar and pestle; two porcelain insulated triangles; pair crucible tongs; small coffee grinder. The above mentioned items may be procured at a cost of approximately $35.00.

The most important item of test equipment which should be available to every engineer is the portable Orsat. It is not suggested that this item be constructed as a home made unit because there are portable units available at prices ranging from $25.00 to $100.00 which are admirably suited for this highly important service, whereas it would probably cost at least $25.00 to procure the parts for assembling one.

*Superintendent of Construction and Engineering, Engineering Department, State Public Welfare Commission, Howard, R. I.

The engineer who is charged with the direct responsibility for the boiler plant should formulate a code for the purpose of serving as a guide to the operators of the station. The proposed guide should be drawn up along practical constructive lines based on confirmed knowledge successfully proven in the field of steam generation. This code should be posted in a conspicuous place to be read by all of the employees engaged in the important phase of boiler operation. The engineer should see to it that each individual understands the intent of the code and also that the provisions contained therein are carried out and continued in force.

Such a code which may be used as a guiding medium to those interested in combustion and the efficient generation of steam. If the boiler plant already exists and responsibility is assumed from the standpoint of operation and not design such a code might be along the lines covered by the following paragraphs:

STEAM ENGINEERS' CODE OF ETHICS

1. Give the boiler setting a minute inspection to ascertain its tightness and general condition under normal operating conditions. Where such defects in the setting, port and door openings are apparent, remedy them.

2. Ascertain in a general way the characteristics governing the type of mechanical stoker or grate, burner or other fuel burning equipment to determine the most efficient method of operation under normal operating conditions.

3. Inspect the boilers both internally and externally and correct any defects noted due to mechanical failure, scale, sludge, slag, leaky baffles or other conditions detrimental to the maintaining of safe and economical operation of the boilers.

4. Inspect the flue connections to the breeching, the breeching itself, connections to the cinder traps or to the chimney and correct any defects observed and maintain perfect tightness and adjustments throughout the entire flue gas travel.

5. Ascertain the characteristics of the chimney or chimneys to serve as a guide, indicating the capacity for present and future expansion.

6. Determine the quality and the source of the water which is available for steam generation purposes and when conditions warrant correction formulate a treatment program for the purpose of eliminating the possibility of scale formation, corrosion or pitting.

7. Ascertain the source of supply and the quality of fuel available and formulate a set of rules governing the combustion of same.

8. Give the accessories which formulate an integral part of the steam generating system a most minute inspection. If mechanical defects, adjustments, steam leaks, missing or lack of insulating covering or other requirements are found as needing attention correct such conditions by inaugurating a carefully planned system of repairs.

9. Calibrate the various items of equipment essentially necessary for the proper maintenance of sustained boiler efficiency and coordinate the efforts of all subordinate employees to the end that the proper calibration be maintained and the relationary air and fuel ratios altered consistently to give the predetermined economies at minimum costs.

10. Institute a cleaning program whereby every one connected with the operation of the boiler plant be charged with certain duties to the end that a boiler plant with a clean, healthy atmosphere be maintained.

11. Make your interest manifest by being constantly alert and cause to have logged on specially prepared forms a daily record of the essentials and other information regarding the operation of the boiler plant. Provide your employer with a cost sheet depicting essential information, coal, oil or gas consumed, steam generated, cost of repairs and anticipated cost of new equipment, payrolls, repairs, etc., and the total cost of generating 1000 lb. of steam.

12. Maintain a close personal contact with the subordinate operators and expound to them the theory of modern combustion, particularly stressing the necessity of determining and maintaining proper ratios of air to coal, oil or gas with proper methods of corrections for varying load conditions.

A tremendous savings was made by the writer in the Central Power Plant at Howard, R. I. by prescribing a general code of ethics for the operators and seeing to it that the rules were strictly enforced. For a time it was necessary to maintain service with the old original battery of nine H.R.T. boilers which were of insufficient capacity for the demands made upon them. By producing results which effected savings approximating several thousand dollars we were able to secure additional funds for new equipment.

This plant is located at Howard, R. I., in what might be termed the geographical center of the State Reservation, set apart by the State of Rhode Island for a group of buildings for the hospitalization of the mentally diseased and criminal insane and for the incarceration of both male and female inmate delinquents, also a group of penal buildings known as the State Reformatory for Men, the State Reformatory for Women and the State Prison and Providence County Jail.

The steam boiler plant constructed in 1915 consisted of eight hand fired horizontal return tubular boilers, aggregating 1400 b. hp. The current generated was considered purely a by-product of the steam generation plant, the prime movers, three 200 kw. high speed reciprocating engines were installed as an integral part of the piping system, functioning as reducing valves. The station contained a 30 t. ice manufacturing plant. The large compressor was driven by a vertical high speed engine, as in the case of the generating engines, this unit acted as a reducing valve. The pumping station consisted of two turbine driven centrifugal water pumps aggregating a capacity of 1500 g.p.m. A similar arrangement of piping connections for these units as for those above mentioned was instrumental in the utilizing of these units as reducing valves operating in conjunction with the low pressure system. The exhaust steam available from these various units was in every case reduced automatically to five pounds with the power cycle and as all of the available exhaust was used, the cost of power required for the various services was considered as practically nil.

In 1928 the State Public Welfare Commission approved of a program and allotted $95,000.00 for the elimination of four 150 hp. h. r. t. boilers and for the installation of two 500 hp. water tube boilers of the cross drum type fired by underfeed stokers.

Having added two new buildings to the system plus several minor additions since the 1928 period and planning for a third building, it was again obvious in 1932 that due to this addition of 35 per cent increase in heating load that the installation of an additional 500 hp. water tube cross drum type boiler would be necessary for augmenting our previous installation of two 500 hp. units.

The contract for the installation called for the following equipment; one 500 hp. water tube rear cross drum type boiler, one multi-retort engine driven stoker, brick setting, installation and insulation of necessary pipes, and accessories including steam flow indicator,

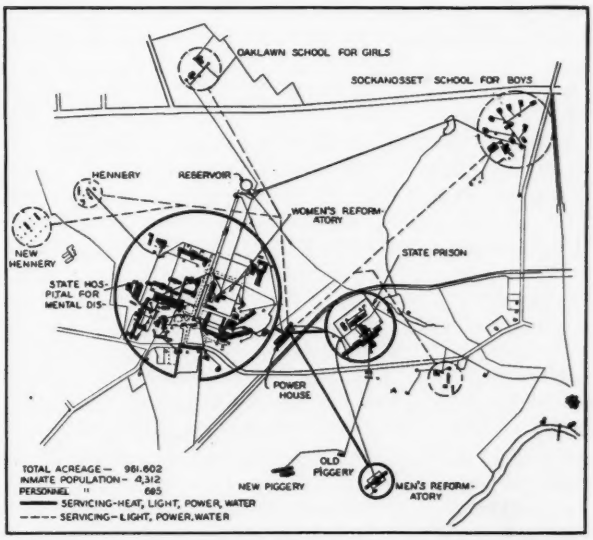


Fig. 2. General map of Rhode Island State institutions located at Howard, R. I.

draft gage, soot blowing system, recording flue gas thermometer and the connecting and coördinating of the several parts and accessories with the master control on the existing installation. The installation of a large cinder trap was also contracted for. This trap was of the stationary baffled type and was designed large enough to cause only slight stack losses at high ratings. This trap was necessary to collect the particles of fly ash which exhausted from the stack as the closeness of the hospital and wards to the Power Plant caused the fly ash and coal dust to filter through the windows or skylights at certain times or periods when prevailing winds occurred. The foundation cost was high because it was necessary to excavate approximately 200 cu. yd. of solid rock to a depth of seven feet, to receive the boiler foundation and the cinder trap foundation. The cost of this unit was:

Foundation for Boiler	$ 1,000.00
500 hp. Rear cross drum type water tube boiler with soot blower system and accessories	9,000.00
Multi-Retort Stoker	6,000.00
Brick Setting	5,500.00
Piping	500.00
Insulation	500.00
Cinder Trap	3,300.00
Cinder Trap Foundation	500.00
	$26,300.00

Total power plant charges for the Central Power Plant are indicated, showing the cost of operating the plant for the fiscal year 1926 and for the fiscal year ending 1933.

Total overall Plant costs for 1926 with old boilers	$131,646.08
Total overall Central Power Plant costs for fiscal period ending 1933 with new boilers was	$ 88,794.09
Difference	$ 42,851.99

Therefore, we find that the 1933 cost following the installation of additional equipment, despite the additional load of 35 per cent in heating demand plus additional power and general service requirements, was equal to a direct saving in cost of 32.5 per cent.

If it were to base the anticipated increased cost due to the extra load imposed on the system and, to base this figure on the cost chargeable to the Central Power Plant in 1926, the saving would be much higher. It would be interesting to note that although no great stress was made on the power plant and its sub-divisions these units play a great part in the general set up of the station. It has been stated that the power and electric facilities obtained from this equipment are considered a by-product and that the cost is negligible, however, in order to visualize the importance which these units have in the general scheme the following information, I believe, should be very enlightening. We find that for the fiscal year ending 1933 that the engine hours run approximated 13,164 hr., producing 849,576 kw-hr. of electricity. The compressor hours run approximated 6557 hr., producing the equivalent of 4098 t. of refrigeration and 1,091,900 lb. of ice. The domestic pump which supplies cold water for the institutional group of buildings ran for approximately 8904 hr. and delivered 263,785,000 g. The boilers which supplied steam for the plant operated approximately 27,584 hr. and generated 310,523,000 lb. of steam while consuming 14,028 gross t. of coal.

Boiler Savings and Meters

Efficient Combustion Requires Air and Fuel Supplied Proportional to Steam Delivered. By K. B. Humphrey

NO MATTER how good a fireman is, he cannot tell exactly what his boilers are doing without adequate metering equipment. This has been definitely proven time and again. With only a steam gage and a water glass, a really good fireman can keep up steam, but there is always some loss in efficiency due to a lack of exact knowledge of other factors which enter into the problem. For instance, he cannot know exactly how much steam is being used. True, a drop in pressure indicates something, it may mean that the

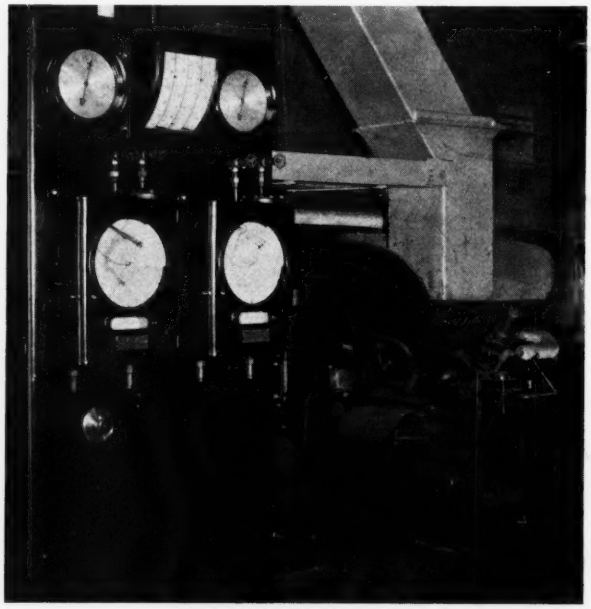


Fig. 1. Typical installation showing the grouping of meters to aid firemen

load is increasing, that his fuel is getting low, or there is too heavy a fire, or too much heat going up the stack, too much or too little draft, or that his tubes need blowing. It is up to the fireman to *guess* what it is that has made the pressure go down. The regulation of the fire to meet varying conditions of pressure and load is a ticklish proposition at best and without adequate metering equipment it is impossible to get sustained good results and high efficiency.

Losses which may be present when a boiler is in operation are intangible. They can not be judged accurately by touch, sense, or sight, though excessive losses will be spotted by an experienced fireman almost immediately. A loss of 5 per cent is not perceptible, but when the annual production of steam runs up to say 12,000,000 lb. a year a loss of 5 per cent means 600,000 lb., or a little over two weeks operation thrown away. There are not many manufacturers who can afford to operate two weeks a year for nothing. Yet the savings made by the installation of adequate meter-

ing equipment may run from 10 to 20 per cent. The return on the investment involved in metering equipment runs from 100 per cent up to 1400 per cent depending upon the size and relative losses before and after meters are used. The average meter installation costs approximately $700 and the annual charges would be about $133 including depreciation, interest on investment, charts, and maintenance.

Naturally there is no questioning the fact that the pressure on the boiler has to be maintained between fairly close limits, and if the pressure is maintained the rest of the outfit will take care of itself, but often to the detriment of efficiency. Now, for any given boiler installation no matter what type of boiler or what kind of fuel is used, there is a certain relation between the amount of air going through, the amount of fuel used, and the load on the boiler.

For instance, for any given load the amount of air going through the firebox should be in proportion. There should also be enough fuel available to give the correct fire. This latter condition is easily judged and can be taken care of by feeding more or less fuel. If the fireman has before him a continuous chart which registers the amount of air being used and the amount

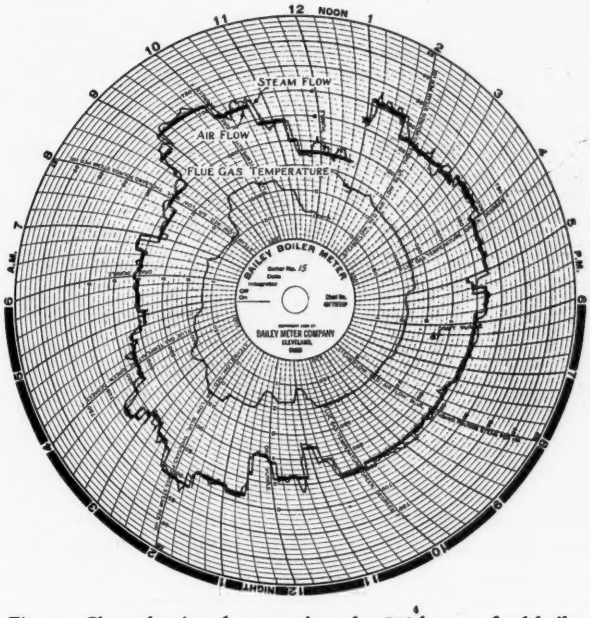


Fig. 2. Chart showing the operation of a 500-hp. gas fired boiler

of steam being used he can make these two values tell him what has to be done. That is, the air and steam should go up and down together.

In order to facilitate matters in keeping the two values in the correct proportion, the two records are contained on one chart, one in blue and the other in red and when the two lines coincide the proportion is correct. How are these proportions worked out? Boiler tests can be made, flue gas analyses taken, and by this means the correct amount of air can be determined for any given load. There will always be an excess of air needed depending upon operating conditions, kind of fuel used, etc. This excess air will vary from 15 per cent with some oil burning installations up to 60 per cent with certain kinds of coal. With the air (or draft) and steam consumption before him at all times it is only necessary for the fireman to regulate his fire so that the two lines coincide as closely as possible and he knows that he is getting the most efficient operation. With a little experience it is possible to get very good results. Tests have been made with the boiler meter covered over and operating in the ordinary way and in every case no matter how good the fireman and how much care was taken the two lines never coincided except for very short intervals of time. Usually an excess amount of air was used beyond that calculated for efficient operation.

In addition to the record of the steam consumption and draft, a third record is usually placed on the same chart which indicates the flue gas temperature. This makes the record complete for the 24 hr. on one chart where results can be easily seen and coördinated.

To sum up the advantages, fuel can be burned at the best efficiency at all times and the best fuel for the installation can be selected, refractories in the furnace wall should last longer due to better fuel utilization and less excessive temperatures, less air can be used and in the case of forced draft, less auxiliary power is needed, capacity can be increased due to more efficient operation, banking losses can be decreased, and actual saving of from 10 to 20 per cent in the cost of operation can be had.

Refrigerated Flies

AN UNUSUAL USE for mechanical refrigeration was reported in a recent "Industrial Bulletin" issued by the Arthur D. Little Laboratories, Cambridge, Mass. We quote directly from their bulletin:

"Although our own record in converting wastes and nuisances to profit is one upon which we pride ourselves, we gladly take off our hats to an industrial engineering friend of ours for a superlative achievement in this field which has just come to our notice.

"A client of his raised mushrooms and fertilized his beds with manure. This practice resulted in the hatching out of vast numbers of flies which were extremely difficult to get rid of.

"The engineer recommended the installation of a suction fan which passed both air and flies over some refrigerating coils in such manner as to chill the flies and then drop them in a dormant state into large milk cans. The installation was made and the flies eliminated as a nuisance.

"The canned flies are now shipped to frog raisers. Upon receipt the cans are immersed in a brine solution, which chills the flies and again renders them dormant. In that condition they are fed to the frogs.

"The mushroom grower now realizes from the sale of flies nearly as much as from the sale of mushrooms.

"The only accomplishment which may seem worthy to rank with this and known to us was that of Professor Elihu Thomson in luring millions of male mosquitoes from the Lynn marshes to their destruction on the walls of an electric furnace by causing the furnace to emit a hum identical with pitch with that of the female mosquito."

Thyratron Tube Excitation

Background of Its Development: Application to a 15,000 Kv-a. Synchronous Condenser and Operating Experience

By PHILIP SPORN

Vice President & Chief Engineer
American Gas & Electric Company, New York

Fig. 1. The FG 53 Thyratron

TO UNDERSTAND fully the purposes behind the thyratron tube excitation system described here and how closely they have been realized, it is necessary to go back to a development that preceded and paved the way for it: the thyratron tube voltage regulator. Although as far back as 1925 mechanical regulators had been brought to a high degree of perfection, they had inherent weaknesses and objectionable features. Thus, the heavy duty imposed on contacts and other moving parts resulted inevitably in wear, and therefore, in frequent mechanical adjustments and other maintenance. Again, the speed of response of the regulating system was always limited by the time lag of both the exciter and the generator (or condenser) fields. The possibility of taking advantage of the characteristics of grid controlled gaseous rectifier tubes (such as thyratrons) capable of handling large amounts of current to provide a power regulator having (a) no moving parts or contacts subjected to heavy duty, (b) smooth and accurate control of regulated voltage, and (c) speed of response characteristics limited neither by the regulator itself nor by the exciter, seemed to offer a way out of all these difficulties. It seemed fundamental that electronic devices could be made to perform such heavy duty service rather than mechanical devices, although actual field experience on these devices, and particularly the tubes, was lacking.

To test the feasibility of the above ideas and to get some practical experience on the device in general and on tubes and tube life in particular, there were installed in 1930 on a standard 15,000-kv-a. synchronous condenser two different thyratron voltage regulator arrangements. The details of these are beyond the scope of this article, but it is important to note that in general the regulator did all that was expected of it: Speed and closeness of control were as expected and tube life, although still too short, was actually longer than predicted. Thus, it was felt that an average tube life of 10,000 hr. was a reasonable expectancy; as a matter of fact, however, the average over 4½ yr. has been approximately 15,000 hr., and for one tube was 17,800 hr. The particular tube used on these regulators was the FG-29 thyratron having a nominal rat-

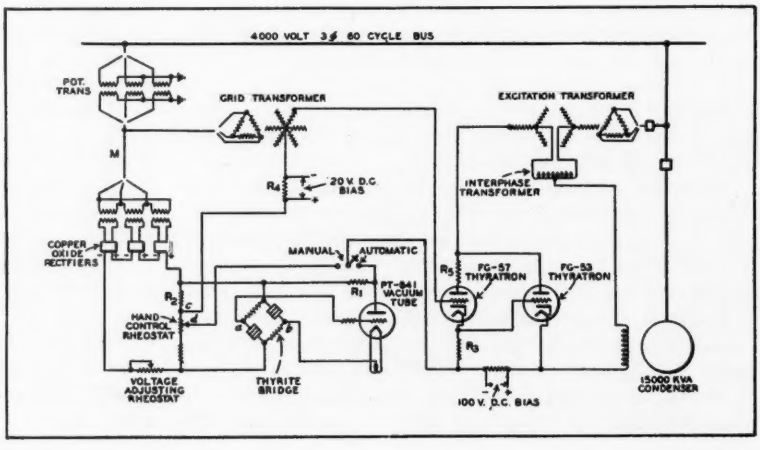


Fig. 2. Simplified connection diagram of Thyratron-Regulator Exciter

Each phase voltage is rectified separately and the three rectified voltages thus obtained are added to provide a d.c. potential which is applied to the Tryrite bridge. The output of this bridge is applied to the grid of the 841 tube.

As soon as the FG-57 fires, a d.c. voltage is developed across R_3 which is applied to the grid of the corresponding FG-53 causing it to fire. After the FG-53 power tube has fired, the voltage applied across FG-57 is limited to the arc-drop of the FG-53 and by resistor R_5; consequently the current through the control tube (FG-53) is reduced to practically zero.

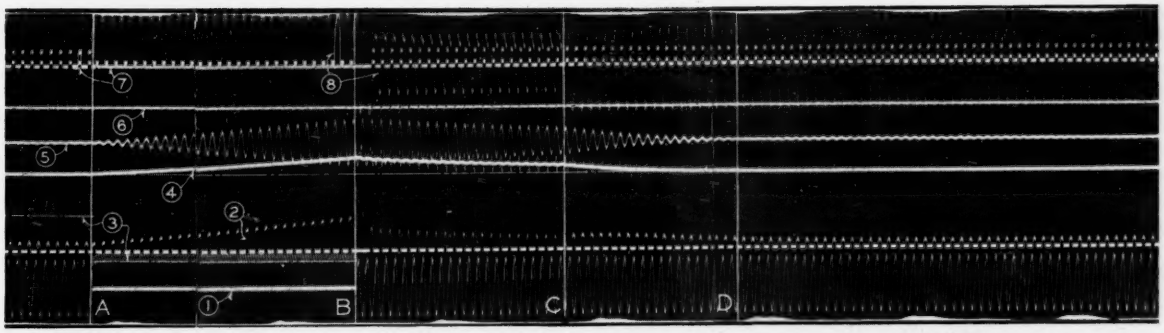


Fig. 3. Oscillogram showing speed of response of the condenser and exciter during a simulated fault, with condenser changing load from 0-15,800 kv-a., leading

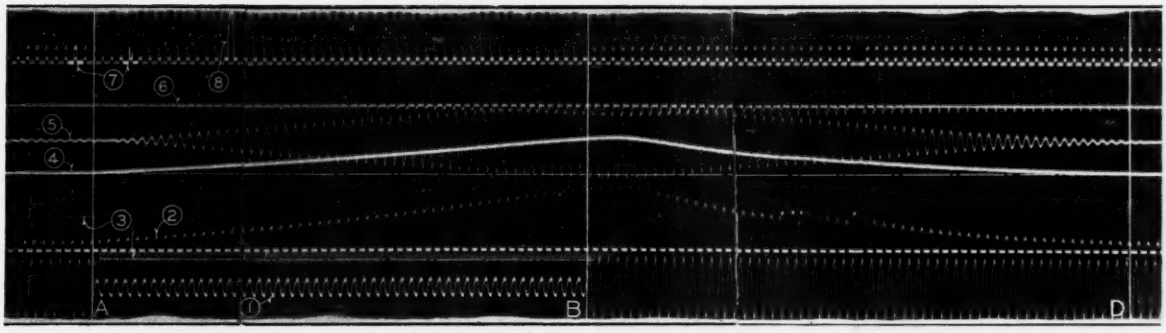


Fig. 4. Oscillogram showing performance when the condenser swing was from 0-38,500 kv-a., leading—150 per cent overload condition.

In the above oscillogram 1, represents A.C. regulator voltage phase 1-2. 2, Plate current No. 3 power thyratron. 3, Condenser field voltage. 4, Condenser field current. 5, Condenser current phase 1. 6, Plate current, No. 3 Control thyratron. 7, Grid current, No. 3 Power thyratron. 8, Anode-cathode voltage, No. 3 Power thyratron.

ing of 12.5 amp. average, 75 amp. instantaneous peak, and 3500 v. peak.

Subsequent to these installations, two more regulators were installed, one on a 20,000-kw. and the other on a 25,000-kw. turbo-alternator. These embodied some circuit improvements and some design improvements in tubes. These installations were made in April, 1931. The additional experience gained with these two equipments was so satisfactory, both from the standpoint of circuit fundamentals and from the standpoint of tube life, that the next step taken, i.e., an all-tube exciter, seemed the most natural and next step and yet fully justifiable in the light of the previously accumulated experience.

Installation of All-Tube Excitation on a 15,000-kv-a. Synchronous Condenser

In August, 1933, a 15,000-kv-a. hydrogen-cooled synchronous condenser was installed at the Suburban Plant of The Scranton Electric Company. This type of machine lends itself best to separately driven exciters; in current practice this would comprise a three-unit motor generator set consisting of motor, exciter, and subexciter. In considering the regulation scheme for this machine it developed that if a larger tube were available, then instead of having a motor, exciter, and subexciter with a sensitizing control circuit acting on thyratron tubes which acted on the field of the exciter, which in turn acted on the condenser field, the tubes controlled by the sensitizing circuit could be made to act on the condenser field directly and thus eliminate not only the motor generator set, but the regulator as well. In other words, the a-c system could be made to give directly a properly controlled and regulated excitation system, more economical than the standard and with all the advantages of speed and simplicity inherent in a tube system. It needs to be kept in mind, however, that whereas in the electronic regulator briefly mentioned above the current output of the electronic device was of the order of 10 amp. full load, an electronic output of 560 amp. full load was needed for excitation on the Scranton machine. Fortunately, the development of the FG-53 tube made this idea practical.

This tube is shown in Fig. 1 and is a 3-electrode mercury vapor tube having a normal rating of 1500 v. and 100 amp. and utilizing a 5 v. heater type cathode. The anode itself is of copper—the development of a method of welding of copper to glass making this possible. As will be noticed from the photograph, it looks rugged; in fact it is not at all the fragile device that the word "tube" generally implies.

Description of Installation

A simplified diagram of the arrangement to give the controlled excitation is shown in Fig. 2. As will be seen from the diagram, each phase voltage is rectified separately and the three rectified voltages thus obtained are added to provide a d-c potential which is applied to the thyrite bridge. This bridge is a device for

magnifying changes in the d-c potential applied to it. It consists of four resistances, approximately equal, connected in a Wheatstone bridge arrangement as shown in Fig. 2. As long as these resistances are equal, the voltage across points "A" and "B" is zero. However, two of these resistances are thyrite, which has the property of decreasing in resistance as the voltage across it rises. Hence, as the d-c potential applied increases the potential of point "B" rises above point "A" and as the applied voltage decreases the potential of "B" decreases with respect to "A". This variation is sufficient so that an increase of 3 per cent in the applied d-c potential above the balance point will change the voltage across points "A-B" from zero to 9 v. Thus, the voltage across points "A-B" serves as a sensitive measure of changes in applied d-c potential and hence, as a measure of variations in a-c regulated potential. This voltage is applied to the grid of the 841 vacuum tube amplifier. The method of controlling the FG-53 power tubes is rather unique and will be described in detail.

Considering the FG-57 thyratron control stage, the resultant grid voltage on this tube depends on (1) a fixed d-c bias obtained across R_4 and R_2, (2) a fixed a-c bias obtained from the grid transformer, lagging 120 deg. behind the anode potential, and (3) a variable d-c bias obtained across R_1 from the output circuit of the 841 triode amplifier, which latter controls the point in the cycle when the FG-57 control thyratron is fired. As soon as the FG-57 control thyratron fires, a d-c voltage is developed across R_3 which is applied to the grid of the corresponding FG-53 power tube causing it to fire, the latter tube being normally biased to cut off by its 100 v. fixed grid bias. After the FG-53 power tube has fired, the voltage applied across the FG-57 control tube is limited to the arc-drop of the FG-53 power tube (about 20 v.) and by resistor R_5, consequently the current through the control tube is reduced to practically zero.

The FG-57 and FG-53 tubes of the other five phases are similarly controlled by the output of the same 841 vacuum tube and thus provide a six-phase exciter whose output is regulated by the a-c line voltage.

The physical arrangement of the equipment is shown in the photograph at the head of page 432 which shows a front view of the entire exciter installation.

The six type FG-53 power thyratrons are located in the screened enclosure at the right. The two 841 vacuum tubes are located near the top of the right hand panel and the six type FG-57 thyratrons are within the enclosure at the top of the adjacent panel. Lower on this panel are six jacks and a meter for measuring the arc-drop of the large tubes. The condenser itself is shown in the background, and the hydrogen control equipment is shown on the left.

Performance Characteristics Determined by Test

The condenser excitation system was put through a very stiff and complete series of tests to determine its performance. Typical results are shown by oscillograms Figs. 3 and 4. The former shows the speed of response of the condenser and exciter during a simulated fault with the condenser changing load from 0 to 15,800 kv-a. leading, and the latter represents a similar condition except that the condenser swing is from 0 to 38,500 kv-a. lead; this represents incidentally a 150 per cent overload condition.

Referring to the above two figures:

1. Represents a.c. regulator voltage phase 1-2.
2. Represents plate current No. 3 power thyratron.
3. Represents condenser field voltage.
4. Represents condenser field current.
5. Represents condenser current phase 1.
6. Represents plate current No. 3 control thyratron.
7. Represents grid current No. 3 power thyratron.
8. Represents anode-cathode voltage No. 3 power thyratron.

In both of the above cases, the fault condition was simulated by lowering the regulator signal voltage at M Fig. 2. When the fault occurred (A) the exciter voltage (3) jumped to its maximum value in less than one-half cycle and held this value until the fault was cleared at B. During the fault the field current (4) and the power thyratron plate current (2) increase rapidly, returning to normal shortly after the fault is cleared. Although the rectified voltage (3) applied to the condenser field contains a high percentage of ripple, it requires no smoothing capacitors or reactors to provide a practically smooth d-c field current (4), due to the extremely high inductance of the condenser field.

There are a few differences between the two cases shown. A study of the wave shapes of Fig. 3 indicates that the field current discharged (from B to C) into one or more of the power thyratrons according to the time constant of the field circuit. One symptom of this action is the slight ripple introduced in the field current. However, beyond C the field current decreases at a forced rate due to regeneration; that is, the stored field energy is transferred back to the a-c supply circuit via the power thyratrons. This action is made possible by the highly inductive load of the field circuit and is controllable within limits. Figure 4 indicates regeneration starting at B. Several one-cycle arc-backs are also indicated in Fig. 4 about midway between B and D.

Traces 6, 7, and 8 of Fig. 4 differ from those of Fig. 3 for the duration of the fault. The former indicates that the d-c bias of the PT-841 control tube overcame the fixed a-c bias over the entire cycle for the duration of the fault so that transfer from one tube to another was by plate voltage rather than by grid bias; whereas on Fig. 3 the transfer evidently took place due to grid bias. This condition can be controlled by adjustment or by proportioning the various voltages involved.

The summation of performance can be given by the following:

1. Response—required less than one cycle to bring field voltage to maximum under short circuit conditions. (The response time is indicated clearly in trace 3 of Figs. 3 and 4.)
2. Maximum field voltage applied under above condition was about 300 v., normal being 116 v. at 15,000 kv-a. leading.
3. Steady state arrived at in approximately 42 cycles for change in regulated voltage sufficient to change condenser load from 3000 kv-a. lagging to full load

leading. For a similar change in the opposite direction, that is from full load leading to 3000 kv-a. lagging, exciter reached steady state in approximately 52 cycles.

4. Sensitivity. Condenser was changed from 3000 kv-a. lagging to 18,000 kv-a. leading by less than one per cent change in regulated voltage.
5. Overall efficiency. 78 per cent at 18,500 kv-a. leading, 57 per cent at 5000 kv-a. leading.
6. Any two power tubes out of service—field current remained smooth, and field current of 600 amp. did not overload remaining tubes.
7. All three tubes of one Y out of service—field current of 300 amp. did not overload remaining tubes.

A few of the special features of the equipment are worth noting:

1. Provision is made for testing the large tubes while the equipment is in operation. In its latest form the testing equipment consists of a milliammeter, a resistor and four copper oxide rectifier buttons; the latter being arranged so that (a) when the anode is positive, a current flows through the resistor and milliammeter which is proportional to the arc-drop voltage and (b) when the anode is negative, current flows through the resistor and rectifier units but not through the milliammeter, thus preventing the high inverse voltage from affecting the reading.
2. The power tubes are each provided with small tubulation heaters automatically controlled by thermostats, making them insensitive to ambient temperature. This heater maintains at approximately constant temperature the pool of mercury in the glass tubulation pendent at the bottom of the tube.
3. Due to the regulator sensitivity being high, some difficulty was at first experienced in going smoothly from manual control to automatic control. This difficulty was remedied by installing a sensitive meter to read the voltage difference between the manual adjustment and the automatic adjustment at the manual-automatic transfer switch shown in the diagram of Fig. 2.

Operating Experience

At the end of the first year's operation the electronic regulator-exciter had been in service approximately 7000 hr. on load. During this time the apparatus operated one hundred per cent through a number of lightning storms and provided generally satisfactory service. The operating personnel has become thoroughly familiar with the maintenance and care of this new type of equipment, which maintenance is limited almost entirely to the checking of tubes.

Of the six FG-57 thyratrons used for control purposes, two were discontinued from service at the end of 6935 and 5858 hr. respectively as they tested somewhat below standard.

The original type 841 vacuum tubes and the 874 voltage regulator tubes are still in service.

The type FG-53 thyratrons, which have a nominal rating of 100 amp. average anode current, 600 amp. peak anode current, and 1500 v. peak, are of recent development. However, four of the original FG-53 tubes are still in service after over 7500 hr. exciter operation, although some of these have not received the full 7500 hr. service under load due to their being taken out for a more detailed checking of condition than could be given them while in service. The remaining two tubes originally installed became faulty after about 4000 hr. operation, due to an open filament in one case and insufficient cathode coating in the other. Of the tubes used for replacement, a few have since failed due to air leaks.

Future Promising

It is evident that the tube troubles experienced are of a nature not unexpected in the development of new and more powerful types of tubes, and it appears reasonable to expect that these difficulties will be ironed out by correcting the tube defects as they appear and by developing circuits which permit the tubes to operate under more favorable conditions. But, on the whole, the development has proven highly successful. The possibilities of applying a thyratron exciter to the solution of turbo-generator problems in connection with hydrogen cooling on the latter to solve not only the exciter problems but the problem of utmost speed of response to promote stability, are now being gone into, and there is an excellent chance of its being found desirable and necessary to utilize it for that purpose.

Coal Problems Reviewed

At the 1935 A.S.T.M. annual meeting in Detroit, Committee D-5 on Coal and Coke presented an extensive report covering its many phases of work. Two methods of test for grindability of coal were presented, one by the ball-mill method, the other using the Hardgrove machine method. The first named describes a laboratory procedure for estimating the grindability of coal. Briefly, the relative amounts of energy necessary to pulverize different coals are determined by placing a sample of coal in a ball mill and finding the number of revolutions required to grind it so that 80 per cent of the sample passes a 74-micron (No. 200) A.S.T.M. sieve.

The Hardgrove method is used to determine the relative grindability or ease of pulverizing of coals in comparison with a coal chosen as 100 grindability. The method is based on Rittinger's Law which states: "The work done in pulverizing is proportional to the new surface produced." A prepared sample receives a definite amount of grinding energy in a miniature pulverizer and the new surface is determined by sieving.

In his paper on the measurement of coal-ash softening temperature, E. P. Barrett described a furnace of the horizontal muffle type so constructed as to permit the cones to be viewed against a background somewhat lower in temperature, so that they are readily visible at all temperatures between 1500 and 3000 deg. F. (815 and 1650 deg. C.). He pointed out that the difference in design between the horizontal muffle furnace and the conventional pot furnace does not affect the results obtained because the conditions in the former meet the requirements of the A.S.T.M. methods for determining ash softening temperatures.

Open Delta *versus* Closed Delta Transformers

By M. D. SIMMONS

ON THREE-PHASE CIRCUITS it is quite common practice to connect two transformers open-delta to supply power service. On a 3-wire 3-phase circuit the connections are made as in Fig. 1, and on a 4-wire 3-phase line each pair of transformers are connected as in Fig. 2. When using transformers this way there are certain economic considerations in the form of financial savings and satisfactory service that should be taken into account. These factors are modified by the size and location of loads and the class of service to be rendered.

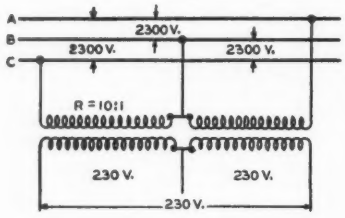


FIG. 1

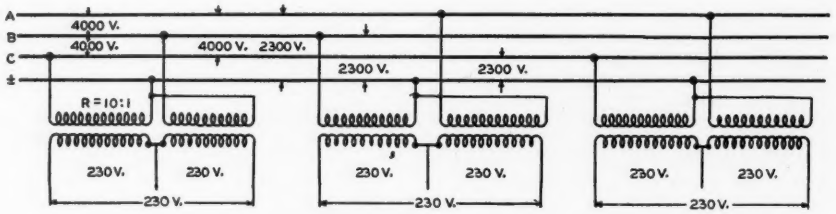


FIG. 2

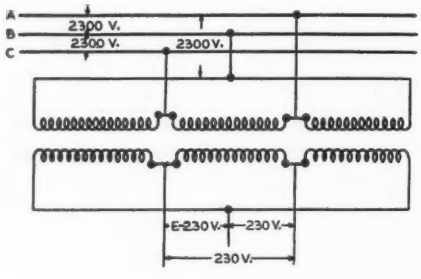


FIG. 3

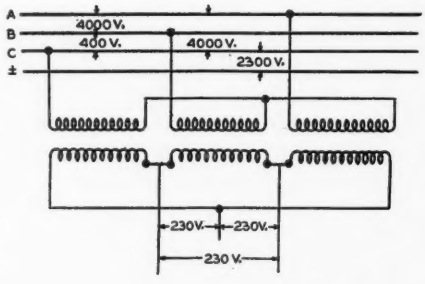


FIG. 4

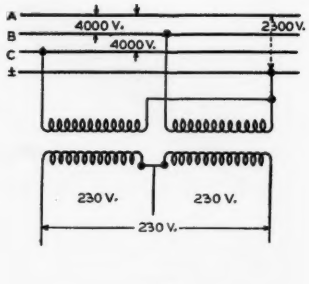


FIG. 5

Figs. 1-5. Transformer connections on 3-wire and 4-wire 3-phase lines, and service rendered with two transformers connected open delta, obtaining 58 per cent of capacity of the closed delta bank

Fig. 1—Two transformers connected open-delta on a three-wire, three-phase line. Fig. 2—Three open-delta banks on a four-wire, three-phase line. Fig. 3—Three transformers connected closed delta on a three-wire line. Fig. 4—Three transformers connected star-delta on a four-wire circuit. Fig. 5—Shows how one transformer may be removed from the bank, Figure 4.

The advantages of using two transformers connected in open-delta as in Figs. 1 and 2 instead of three connected as in Figs. 3 and 4, are not as pronounced as is generally assumed and this will be apparent from a consideration of the table. In this table three 5-kv-a. transformers are compared with two 7.5-kv-a. units, three 10-kv-a. with two 15-kv-a. transformers, etc. It is understood that under normal conditions 15 per cent more transformer capacity is required to supply the same load from an open-delta connected bank as compared to three transformers connected closed-delta. For practical purposes more transformer capacity is usually installed than is required for the connected load. Therefore it will be assumed that the same transformer capacity can be installed whether the open-delta or the closed-delta connection is used.

In the second column of the table, under "Unit Cost Installed," all the costs involved in putting the transformers into place and connecting them up are included, such as labor, material and other contingent expenses. These figures are for installing the transformers out of doors. The total annual costs have been computed for four different pairs of transformer-bank capacities.

The carrying charges, which include interest on investment, amortization, taxes, insurance, etc., have been taken at 15 per cent of the unit cost installed and are given in the third column. This cost can be varied to suit conditions, but 15 per cent is the figure used by one power company. The core loss figures are typical for transformers of a well-known manufacturer. As given in the fifth column from the left, the core-loss costs per year are based on the core loss per

transformer and number of transformers in the bank, times $0.02, the cost of energy delivered at the transformers; times 8,760, the hr. per yr.

A load factor of 0.28 is used and is the same as that of an Eastern power company. This may be considered typical for average industrial loads and is the load factor used in calculating the copper losses. The cost of copper losses per year is calculated as the copper loss per transformer times the number of transformers in the bank; times 0.28; times 8,760, the hours per year; times $0.02, the cost of energy delivered. For example, the cost of the core losses in three 10-kv-a. transformers is equal to $190 \times 3 \times 0.28 \times 8{,}760 \times \$0.02 = \$28$.

When two transformers are connected open-delta, the current in each transformer for the same kv-a. load will be 15 per cent higher than for the closed-delta connection. Since the copper losses increase as the square of the current, they will be about 32 per cent higher in the transformers when connected open-delta than when grouped in delta-delta or delta-star. Therefore when calculating the copper losses of the open-delta connected transformers, the result for two normal transformers is multiplied by 1.32. To take care of this, the copper losses for the open-delta connected transformers in the table, the normal full-load copper losses, have been increased 1.32 times.

Yearly Costs of closed delta and open delta connected transformers

Transformer Bank KVA	Cost Installed, Dollars	Carrying Charges 15 Per cent	Core Loss Per Transformer, Watts	Core Loss Per Year at $0.02 per Kw-hr.	Copper Loss per Transformer, Watts	Copper Loss per Year at $0.02 per Kw-hr.	Total Yearly Cost
3-5	314	47.10	38	19.95	108	15.90	82.95
2-7 1/2	262	39.30	50	17.50	195	19.15	75.95
3-10	435	65.25	60	31.55	190	28.00	124.80
2-15	375	56.20	80	28.00	347	34.00	118.20
3-15	537	80.60	80	42.00	263	38.70	161.30
2-25	498	74.80	120	42.00	515	50.50	167.30
3-25	730	109.50	120	63.00	390	57.40	229.90
2-37 1/2	665	99.70	160	56.00	726	71.20	226.90

From the table it will be noted that there is practically no difference in the total yearly costs of the two sets of transformers. Therefore any advantages that would warrant the installation of open-delta connected transformers must come from other considerations. The first cost is less, but this is not of any consequence unless a large number of transformers are being considered. The figures given in the table may vary with different conditions, but not enough to affect the comparison materially.

One of the objections to using open-delta connected transformers on a 4-wire circuit is the difficulty in balancing the load. It requires three banks, connected as in Fig. 2, each bank carrying equal load to give a balanced load on the system. With a 3-wire system, Fig. 1, a balanced load on the system is obtained if the load is balanced on the two transformers. On a 2,300-v. 3-wire system three transformers may be connected delta-delta, as in Fig. 3, to step down to 230 v. These same transformers may be connected star-delta, as in Fig. 4, to obtain 230 v. from a 4-wire 4,000-v. system. The three transformers have the added advantage that in case of a failure of one transformer on either the 3-wire or 4-wire system the two remaining transformers may be connected open-delta as in Figs. 1 and 5 and supply a load equal to 58 per cent of the combined rating of the three transformers. With the open-delta connection, if one transformer fails the power supply cannot be restored until the transformer is repaired or a new one provided.

The type of service to be rendered is an important factor in determining whether the open-delta or the closed-delta bank should be installed. While actual money saving, under certain conditions, may be shown in favor of the open-delta bank, the intangible cost of an interruption may overcome the apparent saving many times. It is important to consider the type of feeder to which the bank will be connected; that is, whether the feeder is entirely overhead, underground, part overhead and part underground, a radial or loop, and the means provided for sectionalizing in case of trouble; also, whether the transformer bank is on a pole, in a transformer room, and whether the primary feed is overhead or through an underground lateral.

Total Yearly Costs

There is one important exception to remember, not from the viewpoint of interruptions, but from the point of supplying lighting service free from flickers. It has been found with two 25-kv.a. transformers connected open-delta and feeding a 35-hp. motor located on an overhead line three or four miles from the station, that flickers have been produced in residence lamps in the neighborhood. This is due to excessive neutral-wire voltage drop, which reacted through the lighting transformers connected to the same phase wires and neutral. The flickers can be prevented by the installation of a closed-delta bank. In order to avert this occurring, the primary voltage drop can be calculated prior to installation, and if found to exceed 40 volts where 10 to 1 units are to be used, the third transformer should be called for on the initial installation.

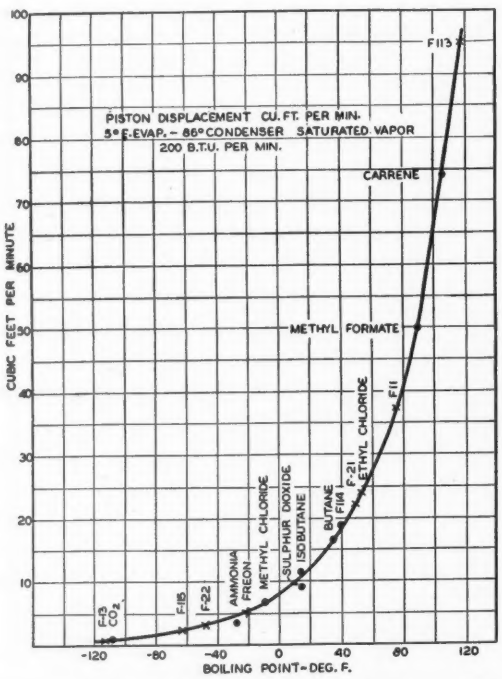
Summing up, it can be said that under certain conditions the open-delta bank can be used to advantage, but where continuity of service is paramount, certain factors must be considered. Some additional line capacity can be provided by its use on a four-wire system, but may require replacing the cable feed-outs from the station for a short distance, to accommodate the increased load which has returned to the phase wires at these points. This means, of course, that when the open-delta banks are installed, precaution should be taken to keep them balanced on alternate phase wires in the field.

Cost of air-conditioning the Tribune Tower in Chicago for June, July and August with steam-jet method of cooling, during 1358 hours is reported as $4100 for coal and $9400 for water.

Freon As a Refrigerant for Existing Systems

Research Program Develops Refrigerant Which Closely Approaches Ideal. Lubrication Requirements, Detecting Leaks. Handling and Safety Precautions. By R. J. Thompson, Refrigeration Engineer, Kinetic Chemicals, Inc., Wilmington, Del.

IN AN EXTENSIVE SEARCH for a universally satisfactory refrigerant certain of the known compounds which date back to the Fourteenth Egyptian Dynasty and others to the time of Homer were investigated and their properties determined. New families of compounds were searched for and produced and all but one family were eliminated as they were found wanting in one or many respects. Out of this search came a new series of compounds which more nearly approached the ideal than any of the others. This series



Compressor piston displacement for standard ton requirements bears a definite relation to the boiling point of the refrigerant

was the *halo-fluor* derivatives of aliphatic hydrocarbons, of which *dichlorodifluoromethane* (F-12) *trichloromonofluoromethane* (F-11), and *dichlorotetrafluoroethane* (F-112) were members. To save time in speaking and writing, and embarrassment in pronunciation and spelling, a code was set up using such letters and numerals as F-12, F-11 and F-114. For the reason that it is always found necessary to explain what the code means, the name Freon was given to F-12.

Freon is sometimes referred to as a hydrocarbon refrigerant and a brief description may help to avoid confusion. There are three families of hydrocarbon refrigerants: First, straight aliphatic hydrocarbon compounds, such as ethane, propane, butane and isobutane, which need not be considered as they are highly flammable and explosive; second, chlorinated hydrocarbon compounds such as methyl chloride, *methylene chloride* or *dichloromethane* and ethyl chloride, some of which are flammable and explosive, others are relatively non-flammable and non-explosive under certain conditions of use but all are relatively toxic; third, halo-fluoro derivatives of aliphatic hydrocarbon compounds containing one or more fluorine atoms of which dichlorodifluromethane, commonly known as Freon or F-12, is the best known member, have good chemical, physical and thermodynamic properties and are less toxic than CO_2 and are non-irritant, non-flammable and non-explosive.

Freon is odorless at concentrations of less than 20 per cent by volume in air, which is equivalent to the release and vaporizing of 65 lb. of liquid into a confined space of 1000 cu. ft. At concentrations higher than 20 per cent the odor of Freon is very mild and similar to that of carbon tetrachloride. The vapor in all proportions is non-irritating to the eyes, nose, throat and lungs, and being odorless and non-irritating will eliminate all possibility of a panic hazard should it escape from an air conditioning, commercial, industrial or household system.

Freon is non-corrosive to all metals used in refrigeration apparatus, and this feature permits the manufacturers a wide selection of materials with which to design and produce efficient condensers, evaporators, compressors, control apparatus and pipe lines. Use of magnesium alloys or aluminum containing magnesium is not recommended in systems where water may be present, as corrosion will result. The water or water vapor has a high corrosive effect on such materials, but this corrosion is neither accelerated nor retarded by the presence of Freon.

Freon, being an excellent solvent, has the ability of dissolving, loosening and physically removing all factory dirt, oxides, scale, soldering flux, factory washing compounds, etc., that may be in a system, and cause the foreign matter to be removed by the liquid or vapor Freon and deposit the heavy particles or corrosion products at the strainer or filter and close the system. Filters of fine mesh screen of sufficient area to prevent blocking in a short time should be provided and so designed as to be readily disassembled to permit cleaning.

Regardless of the fact that Freon has a low B.t.u. refrigerating effect per pound, less than ⅛ that of ammonia which has the highest B.t.u. refrigerating

effect, the piston displacement of a Freon compressor is only 69 per cent greater. The B.t.u. effect of Freon is approximately 1/3 that of methylene chloride, sulphur dioxide, or methyl chloride, or ¼ that of methyl formate, so the Freon compressor has a displacement of 92 per cent, 35 per cent, 5 per cent and 89 per cent less, respectively.

The volume per pound of the refrigerant vapor, together with the B.t.u. refrigerating effect determines the piston displacement, and since Freon has a very low volume per pound of vapor, the comparatively low heat value is compensated. The piston displacement of 5.815 cu. ft. per minute per standard ton is only one of many factors in determining the design of refrigeration apparatus.

It is possible to use present equipment in many cases provided proper cognizance is given to the new B.t.u. capacity, piston displacement pressure control mechanism, regulating valve orifice size, lubrication, and gas velocity. A curve was recently prepared—cubic feet piston displacement plotted against the boiling point of the refrigerant. Strangely enough, these points produce a smooth curve which may be used for predicting displacements when the boiling point is known.

Head Pressures

Operating head pressures will vary with the temperature of the condensing medium, whether an air or water cooled condenser is used, and operating back pressure. Within the wide range of Freon application this operating head pressure in pounds per square inch gage may be closely approximated by multiplying the temperature of condensing medium in degrees Fahrenheit by a head pressure factor which varies with the back pressure as shown by the table. Freon may be used in either air cooled or water cooled compressors, due to relatively low horsepower and exceedingly low compression temperatures.

Tabulation of Head Pressure Factors

Back pressure lb. per sq. in. ga.	Saturation temp. deg. F	Head pressure factor air cooled	Head pressure factor water cooled
0	—21.7	1.33	1.30
10	2.0	1.55	1.40
20	18.0	1.77	1.50
30	32.0	1.96	1.60
40	43.0	2.11	1.70

Freon charged compressors operate at low but positive back pressure down to approximately —20 deg. F., which permit of high volumetric efficiency. Positive pressure prevents moisture laden air from accidentally entering the system, which would reduce the coefficient of performance by the air lodging in the condenser and cause high head pressures and temperatures, and also cause the moisture to freeze out as ice and interfere with the normal operation of the liquid regulating valve.

Since the specific gravity of Freon liquid is from 1½ to 2½ times greater than that of other commonly used refrigerants, with the exception of sulphur dioxide, the float valve ball must be designed of the proper weight and buoyancy to positively control the flow of refrigerant through the regulating valve.

Saturated Freon vapor at 5 deg. F. is much more dense than other compressor gases used as refrigerants, with the exception of carbon dioxide, with the result that the Freon gas velocity must be reduced so as to avoid excessive pressure drops.

Lubrication of a Freon charged compressor is similar to that of a compressor using a hydrocarbon refrigerant such as methyl chloride, ethyl chloride, isobutane, or methylene chloride, which are completely missible with mineral lubricating oil. The lubricant used with Freon charged compressors should be a straight run and properly refined mineral oil and obviously must not contain water sediment, acid, soap, resin, or any substance not derived from petroleum, and must not form wax or gum in the presence of Freon.

The horsepower per standard ton of refrigeration is substantially the same for all refrigerants with the exception of carbon dioxide. It is interesting to note that the theoretical horsepower per ton is: Freon, 0.959; sulphur dioxide, 0.980; methyl chloride, 0.970; ammonia, 0.979.

Detecting Leaks

A Freon leak may be detected by means of a halide lamp, which may be described as a torch burning alcohol which, under normal conditions, produces a colorless flame. A tube fastened to the base of the burner is used to conduct the air suspected of containing Freon vapor through the flame and over metallic copper. Owing to the breaking down of the refrigerant in the flame, a volatile copper halide is formed and the flame color changes from the normal colorless one to a bright green if the air contains as much as 0.01 per cent of Freon. Such a leak is equivalent to the escaping of Freon at the rate of 1 oz. of liquid per month, or ¾ lb. per yr. The leak of a gas or vapor from a system is inversely proportional to the square root of its molecular weight. Freon has a molecular weight of 120.9 as compared with: sulphur dioxide, 64.07; methyl chloride, 50.48; ammonia, 17.03; and air, 29.0.

Moisture must be removed from Freon systems to prevent formation of ice crystals at the regulating valve, prevent oxidation, and prevent intercrystalline embrittlement of brasses when under cyclic stress. This moisture may be removed by heating and evacuating, as has been the practice throughout the industry for years, or by the proper use of a drying agent such as silica gel or activated alumins. Calcium chloride is not recommended because when excessive moisture is present calcium oxide hydrates to calcium hydroxide and finely divided material is removed from the cartridge by the velocity of the Freon liquid and is deposited throughout the system. The miscibility of water in Freon is low and is in the order of 0.006 per cent by weight at 32 deg. F. and 0.015 per cent at 77 deg. F.

It is not necessary to use a gas mask when handling Freon, since it is non-toxic, but large lensed spectacles should be worn to prevent the liquid from freezing the moisture in the eyes. Should liquid come in contact with the eyes, the person suffering the injury should be taken at once to a good eye specialist, avoid rubbing, and should be given the following first-aid treatment: Irrigate the eye with sterile oil, and after irrigation continue to wash with either a weak boric acid or sterile salt solution not to exceed 2 per cent sodium chloride.

A.S.M.E. Spring Meeting at Cincinnati

Registration Totals 681. Irving Langmuir Awarded Holley Medal for 1934. Adolph Meyer of Switzerland Delivers Second Rice Memorial Lecture. W. L. Batt of SKF Industries, Inc., Nominated for President. Next Spring Meeting to Be Held in Dallas

JUDGING from the Spring Meeting of the A.S.M.E., the depression has been passed or at least forgotten by the convention attending section of the industry. For a week, from June 17 to June 22, the Gibson Hotel buzzed with activity as committee meetings, 27 technical sessions, 3 luncheons, a banquet, a stag dinner, two informal parties and a week-end trip to Norris Dam helped to swell the registration to nearly 700.

The Spring Meeting always well attended by college professors on vacation had a larger attendance than usual this year due to the central location of Cincinnati and the attractions offered by the week-end trip to Norris Dam which came between the A.S.M.E. Meeting in Cincinnati and the S.P.E.E. Convention at Atlanta the following week. The attendance was further increased by joint sessions with the Graphic Arts Research Bureau at the Gibson Hotel and the University of Cincinnati.

Nomination of Officers

Nominations for society officers to be elected this fall included the following: for president, W. L. Batt, President, SKF Industries, Inc., Philadelphia, Pa.; for vice-presidents, A. D. Bailey, Superintendent Generating Stations, Commonwealth Edison Co., Chicago, Ill.; J. A. Hunter, Professor, University of Colorado, Boulder, Colo.; R. L. Sackett, Dean, Pennsylvania State College, State College, Pa.; W. A. Shoudy, Orrok, Myers & Shoudy, New York, N. Y.; for managers, W. L. Dudley, Vice-President, Western Blower Co., Seattle, Wash.; W. C. Lindemann, Secretary, A. J. Lindemann & Hoverson Co., Milwaukee, Wis.; J. W. Parker, Chief Engineer, Detroit Edison Co., Detroit, Mich.

On Thursday, at the banquet, President Flanders reviewed the progress of the Society and its increasing importance to the profession over the period of 30 yr. with which he has been connected with the Society. At the conclusion of the meeting he announced the selection of Dallas, Texas, for the 1936 spring meeting and presented the Dallas representative, E. W. Burbank, with a box of bacon as proof to his Texas associates that he had represented them capably and literally "brought home the bacon." The meeting will be held during the Texas Centennial starting June 1, 1936.

During the evening the Holley Medal for 1934 was awarded to Dr. Irving Langmuir, associate director of the General Electric Research Laboratory, for his contributions to science and engineering, especially in the development of the gas-filled incandescent lamp, of the thoriated filament for thermionic emission, of atomic-hydrogen welding, of phase-control operation of the thyratron tube and in fundamental research in oil films. The Holley Medal was instituted and endowed in 1924 by George I. Rockwood, past vice-president of the A.S.M.E., to be bestowed for some outstanding and unique engineering accomplishment resulting in timely public benefit. It was awarded to Hjalmar Gotfried Carlson in 1924; to Elmer Ambrose Sperry in 1928; and to Baron Chuzaburo Shiba in 1929.

Technical papers were presented in 27 technical sessions scattered over a period of three days and grouped under 17 headings. The majority of these papers were of direct or indirect interest to power engineers and the simultaneous sessions made it difficult to decide which to attend. For instance, the prefabricated housing sessions discussed wood and metal factory fabricated units primarily in relation to domestic housing but the importance of this new development to industrial applications cannot be overlooked.

Lubrication

In the Lubrication Engineering session, V. M. Palmer and Horace Smith of the Eastman Kodak Co., presented a lubrication program for an industrial company dealing primarily with practices in their plant, the methods of selecting, testing and applying the lubricants and the savings effected by careful planning. At the Power Transmission session G. M. Bartlett of Purdue University presented a new basis for rating roller chain drives and demonstrated that twice the usual load can be secured with certain combinations of teeth and chain lengths. The Pivoted-Motor Drive was thoroughly analyzed by R. R. Tatnail of J. E. Rhoades & Sons who gave the theory of the design, graphic methods of solution and a comparison of the pivoted-motor and fixed center drives. In the discussion of this paper, P. G. Rhoades of J. E. Rhoades & Sons, W. D. Hamerstadt of Rockwood Mfg. Co. and Walter J. Coppock of the American Pulley Co. told of the development of this type of drive within their own companies and Mr. Coppock presented a motor location chart prepared by their company for the guidance of engineers.

One of the most comprehensive and interesting sessions of the meeting was the hydraulic symposium devoted to three record breaking recent installations for high head, for medium head and for low head. W. M.

White of Allis-Chalmers Mfg. Co. told of the special development and testing work done in connection with the 115,000-hp. Boulder Dam units. This was followed by a paper by R. V. Terry and D. C. Moorhead of the Newport News Shipbuilding & Dry Dock Co., covering the design, fabrication, erection and operation of nine turbines for the Dneiprostroy development in Russia. These 90,000-hp. units are similar in design to the Spier Falls units in this country, and the first was put into service in 1930. Under very unfavorable conditions this unit showed an efficiency of 91.5 per cent and the second unit, recently tested, 92.5 per cent. At light loads a vortex formed in the draft tube and caused some vibration which was corrected by admitting air to the draft tube with a resulting small drop of about 0.5 per cent in efficiency.

R. E. B. Sharp and F. H. Rogers of the Baldwin-Southwark Corp., told of the 45,000-hp., fixed vane propeller units for Wheeler Dam. Ultimate plans for this plant call for 8 units and it is probable that at least some of these future units will be of the movable vane type. This unit with a runner 22 ft. in diameter is the largest propeller unit in this country. R. M. Riegel of the T.V.A. gave further details of this development which is expected to be in service by 1936.

Power and Fuels

One of the promising features of the Steam Power and Fuels sessions was the presence of new, and many of them young, authors shedding a new light on subjects that were thoroughly discussed and forgotten years ago, or a new viewpoint on matters which are little known and little discussed. One of these was a paper on the Division of Load Among Generating Units for Minimum Costs, by J. E. Mulligan of M.I.T. The method presented depends upon the form of input-output curves and brought forth a flood of discussion, mostly of a practical nature, pointing out the difficulties involved in applying the theory to actual plants.

C. H. Berry of Harvard University said that method was in use by the Detroit Edison Co. in 1919 and was thoroughly discussed by the N.E.L.A. the following year. The impracticability of frequent starts and stops causes difficulty in applying the theory. L. J. Levert of the N. Y. Edison-United Electric Light group said that was the crudest of all methods and the extra-starts and stops ate up all the profit in as much as maintenance depended largely upon the starts made. Irving McChesney of the Rochester Gas & Elec. Co. told how they apportioned loads in a system using firm water power, purchased power and steam power and in which a considerable amount of high pressure steam is sold. S. Logan Kerr of Baldwin-Southwark told of the application of this method to hydroelectric plants by Moody and Rogers, then with the Pennsylvania Water & Power Co., and adoptions of its use by the Niagara-Hudson group and the Connecticut Valley Power Exchange in a system using all types of power except windmills. The latter group use a ratio of theoretical to actual power development in the form of loss curves and actual operation runs from 80 to 95 per cent of the theoretical.

A. Egli of the Westinghouse Elec. & Mfg. Co. presented the results of a theoretical investigation of leakage of steam through labyrinth seals in graphical form for practical turbine design. Discussion of the theory was confined to comments by John A. Goff, University of Illinois, and R. L. Scorvil, Stanford University, who questioned the values of static tests and superheated steam to rotational members and superheated steam. Mr. Egli thought the effects of these two factors would be small in actual service. Practical results were discussed by S. L. Kerr who stated that certain labyrinth designs in hydraulic turbines sometimes caused vibration and necessitated removal of one or more rings. Mr. Egli confirmed this as applied to steam turbines and said that it was sometimes necessary to modify the theoretical design somewhat to eliminate the tendency to cause vibration.

Steam turbine leaving losses and vacuum corrections were analyzed by Linn Helander of Kansas State College on the basis of the design characteristics of the last row of blades and certain other data from manufacturers. In the discussion C. H. Berry, speaking for the Power Test Code Committee, said the method was not acceptable for test purposes because it was based on manufacturer's data. John A. Dent of the University of Pittsburgh, Ernest L. Robinson of the General Electric Co. and A. Egli pointed out various limitations. Certain losses such as the leaving velocity loss, pressure drop through the exhaust end and the length of the blade were neglected. Mr. Helander pointed out that the theory was not fully developed, that the method was not intended to replace manufacturer's vacuum correction curves or to be used in the test code, but was intended primarily to assist the engineer in evaluating these losses approximately for his own studies.

Automatic control was reduced, by S. D. Mitereff, to 12 fundamental equations, six of which he said covered most control problems. P. S. Dickey of Bailey Meter Co., P. W. Keppler of Hell Gate Generating Station, E. F. Hanford of Lever Bros., Arthur Edwards of Boston, H. A. Rolnick of Brown Instrument Co. and M. J. Zucrow of Republic Flow Meters Co. questioned many of the statements made, the lack of proper definitions and use of standard terms, the apparent omission of certain fundamental factors and neglect of previous literature and prior art. As Mr. Mitereff was not present no reply was made to these numerous and specific criticisms.

Rolling-in Boiler Tubes

Perhaps the most practical paper of the meeting was the one delivered by F. F. Fisher and E. T. Cope of the Detroit Edison Co. and dealing with Rolling-in of Boiler Tubes. In the method described the correct amount of rolling is determined by measuring the longitudinal expansion of the tube by means of a dial gage clamped around the tube. The holding power of the tube is a function of this expansion but depends upon other factors such as the relative hardness of the tube and drum and the grooving of the drum. In reply to questions, Mr. Cope stated that the tests were made at room temperatures as the most unfavorable condition for the strength at operating temperatures is always higher due to expansion. Mr. Skog of Sargent & Lundy, Inc., felt that this method offered possibilities but appeared to be more expensive. He felt that the tolerance of tubes and holes cited by the authors

was too liberal and stated that his company has used the uniform expansion method on 16 large high pressure boilers with excellent results. The authors said that the expansion method was no more costly than the uniform expansion method, was much more flexible and felt that the tolerances quoted by Mr. Skog were too small for general practice.

Piping theory and the simplification of expansion problems by means of formulae to eliminate laborious steps in computations was presented by S. W. Spielvogel of the Brooklyn Edison Co. and S. Kameros of the New York Edison Co.

Radiant Heat

At the first Fuels session, H. O. Croft and C. F. Schmarje of the U. of Iowa described an absorption calorimeter with a fused quartz window and the application of this calorimeter to the heat transfer by radiation in boiler furnaces. Development of formulae in their original paper was modified in the light of recent tests and the modified formula includes a dirtiness factor determined from the fraction of surface covered by slag or fly ash. Calculated heat transfer by radiation increases with the dirtiness factor D up to a maximum at $D = 0.5$ and then decreases up to $D = 1$. Their results show a much larger percentage of convection heat transfer than the Wohlenberg Formula which in turn gives lower total heat transfer than the Hudson-Orrok Formula.

In discussion, Geo. Orrok reviewed the development of the Hudson-Orrok formula from test results and says it has been applied to many boilers and gives results within 5 per cent. The coefficient of 27 is, however, varied in use by experience and may vary from 23 to 30. He felt that due to the low velocities at the walls that the convection transfer should not be as high as shown by the authors. This thought was also expressed by W. L. DeBaufre of Combustion Engineering Co.

R. A. Sherman questioned the accuracy of the absorption calorimeter particularly as it had a low absorption coefficient and was calibrated only over a limited range. He and several others felt the use of a dirtiness factor as used was rather indefinite and expressed an interest in the relative screening effect of slag and fly ash. Mr. Schmarje said that apparently slag and fly ash had the same effect. Mr. Gilman of the Columbia System confirmed this and reported the results of tests on a slag tap furnace to increase the furnace temperature and superheat by covering some of the water cooled surface by refractory.

Slag Tap Furnaces

Development of a simple cheap slag tap furnace built up from a concrete floor and with no basement was described by J. H. Strassburger of the Weirton Steel Co. These boilers were Stirling units installed for blast furnace gas in 1926 and later converted to pulverized coal and dry bottoms with a substantial increase in capacity. Development of the slag tap bottom was the result of an accident in fusing the ash during high rating and was so successful that it was retained. James W. Armour of the Riley Stoker Co. told of tests made on another type of high fusion ash coal with equally good results, and Mr. Jones of the West Virginia Pulp & Paper Co. told of the proposed installation of similar units in their plant. R. M. Hardgrove of Babcock & Wilcox Co. thought that such a floor would not work on a coal high in pyrites. Joe Crane of Combustion Engineering Co. told of a continuous tapping ring type furnace in another station and felt that that design offered the best possibilities. Mr. Strassburger said that the designs given were not offered for universal application but as a development which offered a successful solution of their problem with the coal they used at very low cost and with increased capacity.

In the final Fuels session, James W. Armour of the Riley Stoker Co. presented a paper discussing the possibilities of pulverized coal for small boilers and showed typical installations made by or participated in by several companies including the Riley Stoker Co., Babcock & Wilcox Co., Erie City Iron Wks., Foster Wheeler Corp., Fuel Economy Engineering Corp. and Strong-Scott Mfg. Co. This paper compared the first and operating costs of a typical stoker and pulverized fuel plant of the same size and came to the conclusion that pulverized coal warranted serious consideration by owners and purchasers of small boilers either for new equipment or the replacement of hand firing.

Influence of Coal

In the discussion H. G. Lykken of Strong-Scott Mfg. Co., gave some of the combustion factors involved in small boilers. The question of fineness and suitability of different coals then received considerable attention and B. E. Tait of the National Cash Register Co., H. P. Reid of the Atlas Portland Cement Co. and A. M. Kinney, consulting engineer, contributed considerable data on the question of grinding, mill capacities and related subjects with particular reference to the coals of the Cincinnati territory.

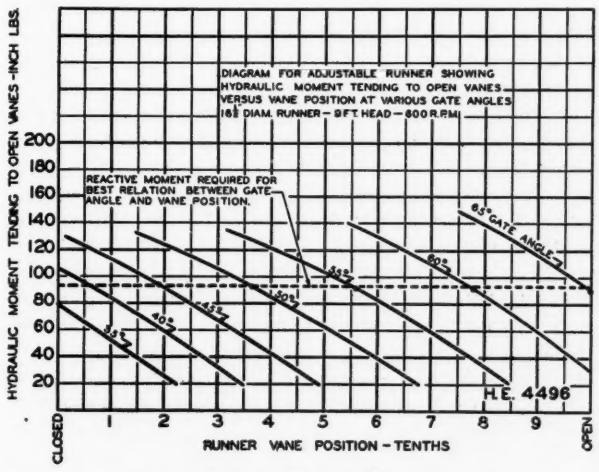
Although the general trend of the session was toward pulverized coal, the stoker side was well presented by R. L. Beers of the Detroit Stoker Co. who gave statistics to show that over the last few years small boiler pulverized coal installations were measured in tens, the small stoker installations were measured in hundreds, and thought that the trend was toward stokers. The general symposium on pulverized coal firing in the Cincinnati territory scheduled on the program, did not materialize due to the unexpected absence of the leader, J. C. Hobbs, in Europe. Discussion of Mr. Armour's paper did, however, bring out many points originally intended for the symposium and the additional time allowed for discussion of his paper did much to clarify the pulverized coal problem and answer many questions for prospective users of this type of equipment.

Adolph Meyer of Brown, Boveri & Co., Baden, Switzerland, delivered the second Calvin W. Rice Memorial Lecture instituted to foster international relations and commemorate action of the late secretary of the Society in that direction. Dr. Meyer spoke on the development of the Velox boiler, an outgrowth of work on gas turbines and the Buchi supercharger on Diesels. At velocities approaching that of sound heat transfer is high and the boiler, with a furnace operating at a high positive pressure, gives heat transfers which on the basis of conventional American rating would be equivalent to 3300 per cent. An article on the boiler by Dr. Meyer will be published soon.

New Automatic Adjustable Blade Turbine

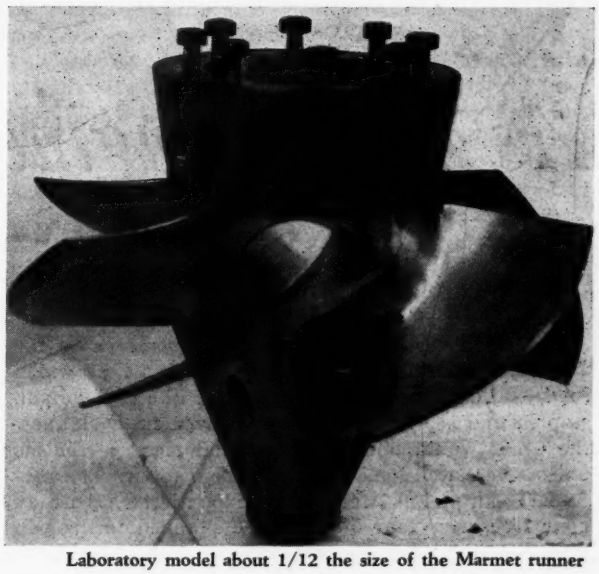
TWO INTERESTING hydraulic developments are under construction in West Virginia by the Kanawha Valley Electric Co., a subsidiary of the American Gas & Electric Co. Both projects are on the Kanawha River, the first at Marmet about 10 mi. and the second at London, about 25 mi. upstream from Charleston; both will operate under a head of about 23 ft. At London one 7250-hp. Kaplan adjustable blade and two 6800-hp. propellor type fixed blade wheels will be installed. At Marmet a similar arrangement will be used except that a 7600-hp. adjustable blade turbine of a new type will be substituted for one of the two fixed blade units. The turbines are now under construction, the Kaplan units for both plants in the shops of the I. P. Morris Division of Baldwin-Southwark Corp., the three fixed blade turbines and the second adjustable blade unit for the Marmet plant in the shops of the Newport News Shipbuilding & Dry Dock Co. Both plants are expected to be in operation late this year.

The adjustable blade turbine for the Marmet Plant will be built with an experimental runner of the automatically adjustable type of new design. Heretofore this runner has been built only in model sizes for experimental purposes in the laboratory of the Newport News Shipbuilding & Dry Dock Co.



Experiments with models of this runner have been conducted in the laboratory for a number of years and Fig. 1 is a photograph of one of these models. Vanes of this runner are automatically adjusted entirely by the flow of water through the turbine. In other respects the turbine is of standard construction.

Runner vanes are pivoted on roller bearings and connected through gears and racks to a dashpot in the runner hub. Each vane is pivoted slightly above the center of pressure so that the water flow creates an hydraulic moment which tends at all times to open or increase the pitch of the vanes. This moment is opposed by a device which creates a reactive moment that tends at all times to close or decrease the pitch of the vanes. The reactive device may be pre-compressed springs or any one of several other devices.



Laboratory model about 1/12 the size of the Marmet runner

There is, of course, a maximum efficiency position of the vanes corresponding with the speed, head and load under which the turbine is operating. Experiments have demonstrated that if the runner vanes are properly proportioned and pivoted the reactive moment required to maintain best efficiency for a given installation will be practically constant within the usual variations of head and load. The chart illustrates a typical diagram obtained from model tests showing the hydraulic moment tending to open the vanes plotted against the position of the vanes for various angular positions of the wicket gates. The reactive moment necessary to cause the vanes to assume their most efficient position is also shown.

It will be noted from the diagram that the hydraulic moment increases with the wicket gate angle, i.e. increases with load on the unit, providing the runner vanes are held in a fixed position. When the wicket gates open sufficiently the hydraulic moment overbalances the built-in reactive moment and the runner vanes are forced open. Movement of the runner vanes stops when the hydraulic moment equals the reactive moment. For each change of load the governor adjusts the wicket gates while the runner vanes move automatically to a new balanced position.

Relation between the position of the vanes and the position of the wicket gates is not fixed but varies with the head and speed. As the head is decreased the runner vanes close to a decreased pitch position relative to the position of the wicket gates which action is also necessary to maintain best efficiency under the reduced head. In case some load is dropped and the unit speeds up the runner vanes tend to move to a decreased pitch position to reduce the power output. The opposite action takes place upon increase of load. Thus there is an inherent tendency towards self governing.

Another interesting feature is that the vanes open wide when the turbine is started and this gives maximum starting torque. As the turbine approaches normal speed with no load on the unit, the vanes move to the closed position after which they move to the position required by the load.

As One Engineer to Another—

G. F. Discusses the Comparison of Fuels with the Chief. By G. F. WETZEL, M. E.

AS I SAT down to my desk on my return to the office early in the afternoon, I saw a note which read,—"Your friend the Chief would like to have you stop in and see him as soon as convenient." I knew the Chief would not leave a special message for me unless there was some unusual reason for it. The program I had planned for the afternoon left me with an hour free after four o'clock, so I planned to drop in and find out what he wanted.

After completing the work scheduled, I drove over to the Chief's plant and found him with the same worried look on his face that I had seen on one or two previous occasions when he had a serious problem on hand.

"Hello, Chief," I greeted him. "You look as if the Boss had just told you to build him a new power plant by tomorrow, and you had forgotten all the answers."

"Thanks for coming over, G.F.," he replied. "It isn't as bad as that, but I guess I have forgotten all the answers, in fact, I think I have forgotten more than I ever knew. The latest is that we may be burning gas here before very long. One of the industrial men from the gas company was here talking to the Boss, about changing over to gas for our fuel. Then the Boss called me in to give me the information he had, and to ask for a written report, and he wants it quickly."

"Well, give it to him," I told him. "You have a lot of background now. Use it. What did the gas man tell you?"

"Of course, everything we are doing now is all wrong, according to him. He should be burning gas. Oh, yeah! The price the company is quoting is 2c per therm. What do I do next?" he asked.

"Since an oil man might call on him tomorrow, maybe we had better check your present fuel,—coal—with both oil and gas, and see how the heat costs of the three compare," I suggested. "The first thing to do is to stop and see just what we are trying to do, and what we have to do it with. Your job is to see that steam is available for power, processes and space heating, and steam requires heat. The boiler doesn't care whether the heat it absorbs and transfers to the water comes from coal, oil, or gas,—or for that matter from sawdust. There must be an adequate supply of heat to carry the load, and that is the prime consideration.

"Now let's consider how these fuels are bought. Coal is purchased by the ton, oil by the gallon, gas by the therm."

"Therm?" the Chief interrupted, with a question in his voice. "That is what the gas fellow mentioned, too. What is a therm, anyway?"

"A 'therm' is a name given to a unit of 100 thousand B.t.u.,—a heat quantity. Gas is metered by volume, but charged by the heat content, in the Chicago territory. The number of cubic feet per therm is found by dividing 100,000 by the calorific value per cubic foot. Our gas in the Chicago district is a mixture of natural gas brought up from Texas by the high pressure pipe line, and manufactured gas. This mixture will rate 800 B.t.u. per cubic foot. Thus a therm will mean 100,000 ÷ 800 or 125 cu. ft.

"Obviously, if we are going to compare the cost of these fuels we must convert the other two to a therm basis. We will take coal first. The cost per therm will be the cost per ton divided by 2000 (which is cost per pound) multiplied by the number of pounds required to supply 100,000 B.t.u. which is 100,000 divided by the B.t.u. per pound of coal. Suppose we use symbols and get it in formula form:—

C_t = cost per ton in cents

H_{fc} = calorific value per pound coal

$$\text{Coal cost per therm} = \frac{C_t \times 100{,}000}{2000 \times H_{fc}} = \frac{50 \times C_t}{H_{fc}}$$

"You had better put this formula down in your note book, Chief, because it may come in handy, and you will be smart to have it where you can find it, unless you are sure that you will remember how to figure it out for yourself.

"The cost per therm for oil will be found in a similar way,—the cost per gallon multiplied by the number of gallons required to supply 100,000 B.t.u.:—

C_g = cost per gallon in cents

H_{fo} = calorific value per gallon

$$\text{Oil cost per therm} = \frac{C_g \times 100{,}000}{H_{fo}}$$

"No. 5 oil as delivered in this territory will run in gravity from about 14 to 22 deg. Baumé and it is important to know the gravity because the heat content varies quite consistently with the gravity. Here are the values taken from thousands of tests by the Kansas City Testing Laboratory:—

Degrees Baumé	B.t.u. per gallon
14	152,342
16	150,912
18	149,522
20	148,171
22	146,842

The No. 5 oil is often specified as 18-20 Baumé but actually most deliveries have a gravity of 14 to 18, so we figure an average value of 150,000 B.t.u. per gallon.

"You know your coal price and heat value. The No. 5 oil which is used in most boilers above household size will cost at present here in Chicago, 4.75 cents per gallon in tank wagon lots, and will run approximately 3.4 cents per gallon in carloads on the track. Now you wouldn't want me to do it all for you, so go ahead and find the cost per therm for coal and oil, then list the three, and see what we get."

From our previous discussions the Chief had learned the value of putting down his problems completely, so it was only what I expected when he showed me the therm costs all neatly worked out a few minutes later:—

Coal cost per therm = 50 × 525 ÷ 12,200 = 2.152¢ (truck loads)

Coal cost per therm = 50 × 420 ÷ 12,200 = 1.721¢ (car loads)

50 is 100,000 ÷ 2000; 525 and 420 are prices in cents per ton for truck and car loads, respectively, 12,200 is calorific value of coal.

Oil cost per therm = 4.75 × 100,000 ÷ 150,000 (tank wagon)

= 4.75 ÷ 1.5 = 3.167¢

Oil cost per therm = 3.4 × 100,000 ÷ 150,000 (car loads)

= 3.4 ÷ 1.5 = 2.267¢

Gas cost per therm (quoted by gas company)=2.0¢. Whether you compare the truck load or car load prices of coal and oil, be sure that the comparison is on the same basis, unless in the exceptional case where oil could be handled in car lots, but coal could not be handled in cars and would have to be bought in truck loads.

"Now it would be a shame if you did not get a chance to exercise the knowledge you have so painfully acquired during the past several months. So go ahead by yourself and figure it out.

"Let me give you a word of caution, Chief. Don't overlook your efficiency values in figuring your steam costs. You will remember we figured the efficiency of your plant, burning coal, at 67.8 per cent, as I recall it. On this basis use 75 per cent for oil, and 80 per cent for gas.

"If all the heat released from the fuel by its combustion were absorbed by the boiler, then the net heat added in generating steam would be the same as the total calorific value of the fuel burned. But we know that there are losses, therefore the amount of fuel required will be larger, and will be inversely proportional to the efficiency. Thus if efficiency were 75 per cent, the fuel required would be (100 ÷ 75) times the heat absorbed by the water in being heated from feed temperature to the boiling point and changing into steam.

"Look up your previous notes, and find the net heat added per pound of steam by the boilers. I will take a look around your plant to see if I can find the usual amount of dust, dirt, and disorder while you are working it out."

"The usual amount of dust, dirt, and disorder in my plant is zero, and you know it, G. F.," the Chief retorted, "But go ahead." This was a tender spot with the Chief because his whole plant is as near spotless as a coal burning plant can be.

When I got back to his office he showed me his figures:—

Using coal (therm cost 1.721¢) (car-load basis);

1 lb. steam requires 1064 ÷ 100,000 therms (1064 B.t.u. is net heat added per pound of steam by boiler)

1000 lb. steam = 1064 × 1000 ÷ 100,000 therms = 10.64 therms. Efficiency = 67.8% = 0.678

Fuel cost per 1000 lb. steam = 10.64 × 1.721 ÷ 0.678 = 27.008¢

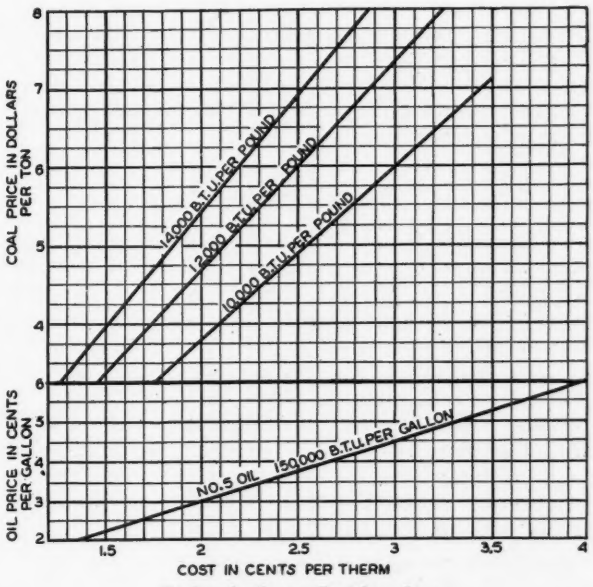
Using oil (therm cost 2.267¢) (car-load basis)

Fuel cost per 1000 lb. steam = 10.64 × 2.267 ÷ 0.75 = 32.16¢

Using gas (therm cost 2.0¢)

Fuel cost per 1000 lb. steam = 10.64 × 2.0 ÷ 0.80 = 26.60¢

"That is a good piece of analysis, Chief. If you remember what we have been over, and what you have done, you can compare the fuel costs of anything the Boss may want you to burn. Now, I believe you said he wanted a report on the advisability of burning gas in your plant. On the basis of the fuel costs with the three fuels, per 1000 lb. steam, you will save just 0.408¢, less than one cent, per 1000 lb. As I remember it, your steam production will run about 40,000 lb. per hr. which would mean a saving of $0.1632 per hour. If we figured an average of 48 hr. per week, for, say, 45 weeks per year to allow for decreased demand in the summer time, that would amount to $350.00 per year in round figures. Considering the cost of burner equipment, and piping cost that would not be much of a return, apparently."


COAL PRICE IN DOLLARS PER TON
14,000 B.T.U. PER POUND
12,000 B.T.U. PER POUND
10,000 B.T.U. PER POUND
OIL PRICE IN CENTS PER GALLON
NO. 5 OIL 150,000 B.T.U. PER GALLON
COST IN CENTS PER THERM

Coal and oil cost diversion chart

"Why do you say apparently?" the Chief inquired.

"Because there are other important considerations in addition to the cost of fuel in generating steam, which you know as well as I do," was my answer. "For instance, you realize of course that there will be a lot of brick work to be done, to make your furnaces suitable for burning gas, and you will have to pull out quite an investment in stoker equipment.

How much longer will the stokers have to stay in operation before they are depreciated down to scrap value, —ten years?"

"I believe they would be good for at least 10 yr. more with normal attention and repairs," he told me.

"Then the undepreciated value must be written off and charged against your plant account. Did the gas man tell you anything about reserving the right to shut off the gas on 30 minutes notice, or something like that?"

"Yes, he did, and the Boss called my attention to it, too. And that means stand-by equipment to operate in a boiler setting equipped for burning gas, which would mean either powdered coal or oil."

"Right you are, Chief. You will then have to compare the therm cost, oil storage, handling and burning equipment, with the coal therm cost and the cost of coal pulverizers, blowers, piping, conveyors, etc.

"In making your summary of advantages and disadvantages, you must give credit for the elimination of coal storage space, coal handling, ash handling and disposal cost, if oil were used for the stand-by fuel, and then consider the costs of oil burning equipment, storage, and handling.

Graphic Solution

"With the figures we used above, it would not seem advantageous to change your fuel. If the gas were quoted at 1.5¢ per therm instead of 2¢ then there would be something worth giving serious consideration to, since that would be equivalent to oil at 2.12¢ per gallon, or coal at about $3.05 per ton, with a calorific value of 12,000 B.t.u. per pound. I recently looked inside a gas-burning boiler furnace with a capacity of 500,000 lb. of steam per hour,—one boiler with ten times the capacity of your whole power plant,—and really, Chief, it is one of the prettiest sights you will ever want to see.

"In order to make quick comparisons of fuel costs, on a therm basis, I drew up a graph. I think I have one in my brief case. Yes, here it is. To use it, select your oil prices at the left, follow along the horizontal line to the right to the diagonal line. Then drop vertically down to the 'Cost in cents per therm' and read it directly. With coal, select the price per ton, follow the horizontal line to the diagonal line nearest to the correct calorific value, then interpolate between the lines. For example, if your coal cost were $5.50 and had 11,000 B.t.u. per pound, you would follow the horizontal line to a point half way between the 10,000 B.t.u. line and 12,000 B.t.u. line, then down, and read 2.55¢ per therm.

"To return to your report, if you were going to make the change, and were to use oil for your stand-by fuel, you should allow for at least a week's supply of oil. Figure out how much it would take."

I watched the Chief to see how he would go at this problem. After one false start he put down an equation which seemed to satisfy him, and proceeded to carry out his calculations:—

$$\text{Gallons oil} = \frac{1064 \times 40{,}000 \times 48}{150{,}000 \times 0.75} = 18{,}159 \text{ gallons (per week)}$$

(1064 is B.t.u. per lb. steam under given conditions; 40,000 is pounds steam per hour; 48 is hours per week; 150,000 is B.t.u. per gallon; 0.75 is 75 per cent efficiency).

"Okay, Chief, you handled that nicely. You can see, then, that you will need 18,000 gal. storage capacity as a minimum.

"You can gather from this discussion that there are many factors to be considered besides the purchase price of the unburned B.t.u.,—auxiliary equipment and power to operate it, capital investment, depreciation, maintenance, probable continuity of operation, fuel storage space and, or, storage equipment for fuel, fire hazard, adequacy of fuel supply, labor, refuse disposal cost, any conditions peculiar to your plant. I think that is about all the factors that should go into your report so that the Boss will have what he wants to arrive at an intelligent decision."

Artificial Daylight for Floral Displays Fools Flowers

Mixing the light of high intensity mercury lamps with that of incandescent lamps to provide illumination of daylight color quality for floral displays was successfully tried out for the first time at the 1935 Flower Show in New York City. Special fixtures constructed of sheet steel, aluminum painted, and equipped with frosted glass plates by the M. I. Salit Company, contained one Westinghouse 400-watt high

intensity mercury lamp. Artificial "daylight" preserved true horticultural harmonies in the display of the New York Botanical Garden.

Says T. H. Everett, Horticulturist of the New York Botanical Garden, "various species of South African Daisies in our display at Grand Central Palace, close their petals and retire for the night when darkness falls.

"Under this light we have been agreeably surprised to find that they remain open and display their beauty throughout the evening, much to their personal dislike perhaps but much to the pleasure of visitors. I have always felt that the right kind of light would keep these flowers in bloom at night and the nearly daylight color of this light undoubtedly contributes to the phenomenon."

Case Studies in Power Economics

Conducted By
ZUCE KOGAN,
Kogan Industrial Service,
Chicago, Illinois

ELIMINATION OF TROUBLESOME ROTARY CONVERTOR REDUCES ANNUAL POWER BILL BY $1500

BY TAKING advantage of changing conditions in his plant, many a plant owner can eliminate considerable trouble and avoid large expenditures which may, at the moment, appear necessary. Many a plant holds on to obsolete equipment for the simple reason that this obsolete equipment has grown as a habit on them and they try to conform other conditions in the plant to fit this obsolete equipment, the wiser thing being to get rid of that "bad habit" by merely disposing of it completely.

One of our clients, an owner of a manufacturing and mail-order house, had a plant which consisted of two buildings, building No. 1 and building No. 2, which were 200 ft. apart. Fifteen years ago each building consisted of part manufacturing and part storage. He was generating his own direct current, the generating equipment being located in building No. 1 and power was sent by an underground line to the other building. As the business began to grow he found it advisable, in order to reduce the cost of production, to confine his manufacturing to one building and subsequently, all the larger equipment of building No. 2 was moved to building No. 1, where the generating equipment was located.

It so happened that upon enlarging his storage space in building No. 2 and adding to it larger executive offices, his lighting load increased almost in the same proportion as the amount of power removed from it to building No. 1. The power requirements in building No. 2 averaged around 400 kw., this being divided equally between light and power. This increased lighting load could not be handled by the generating capacity of building No. 1, and even though he could handle the power load of building No. 2, he decided to purchase alternating current from the local utility to supply both the lighting and power for building No. 2. Since for 50 per cent of his load he required direct current and since the lighting was on the power circuit, he purchased one 400-kw. rotary convertor.

As time went on, more and more of the motors in building No. 2 were moved to building No. 1 and a large retail store was added to building No. 2 in such a way that the amount of power required by building No. 1 remained practically the same only that the light became 90 per cent of the total power, leaving a total of 70 odd hp. in building No. 2. This condition existed about 5 yr. ago and went on for some time, the local utility supplying alternating current power to building No. 1, this a.c. being converted to supply a large lighting load and a small motor load. In the meantime, the rotary convertor began to show trouble, excessive sparking set in, maintenance on the commutator became very frequent and it looked like either a new commutator was required, or better yet, a new rotary convertor. In either case, a considerable expenditure was necessary.

After surveying his plant, we advised against any repairs on the rotary convertor and against the installation of a new rotary convertor. We suggested removing the rotary convertor altogether and bringing in the alternating current from the local utility directly. In order that he should be able to do so, we recommended disconnecting the direct current motors from the lighting system and connecting them to the old existing line running from building No. 1 to building No. 2. Since the motors were confined in a small space, the cost or wiring would amount to very little.

This our client did. He found no difficulty in bringing in alternating current from the local utility for his lighting system as it was a three-wire circuit. The extension of his old line to the motors and the rewiring amounted to about $400. After operating several months without the rotary convertor we found that there was a reduction in the cost of lighting for building No. 2 in the neighborhood of 6 per cent. This saving could be seen very readily because his monthly lighting cost was quite uniform. This 6 per cent reduction in the cost of power was entirely due to the elimination of the conversion loss from alternating current to direct current. On his $1100 lighting bill this 6 per cent represents a saving of $66 per month or approximately $800 a year.

He further discovered that the purchased power for his motor load was very high. This load was highly intermittent in nature, hence it had a high demand in comparison with energy consumed. Even though he earned a low rate on his energy due to the comparatively large consumption of energy for lighting, the demand charge was high. By switching over the small motor load to his generating equipment, a load small enough to be conveniently carried by his present generating equipment almost unnoticeably, he reduced his power cost for building No. 2 to almost nothing. The reduction in the demand charge alone on his motor load amounted to $60 a month or around $700 a year. The increase in steam consumption for generating the additional power, even though he had to waste the additional exhaust steam, was negligible. Hence, he realized by making this arrangement, a total yearly saving of $1500 per year.

The greatest advantage in removing the rotary convertor, however, was the fact that he was able to eliminate troublesome equipment without the necessity of going into large bills or investment into new equipment, the investment incurring with it fixed and operating charges. This $1500 saving per year was incidental, and amounted to little compared with the convenient and trouble-free present arrangement.

Readers' Conference

Instrument for Outlining Irregular Curves

RECENTLY developed for the draftsman is an instrument that will form curves of practically any degree. The drawing edge of the instrument is of spring steel, backed by a strip of rubber which grips the paper, minimizing the danger of any movement which might blot the ink.

When the desired curve is found by moving the adjustable slide along the rigid carrier, the slide may be clamped in position and the curve drawn.

Kansas City, Mo. ALLEN P. CHILD.

Rubber backing provides space for finger rest

Turbine Oil Fires

SERIOUS fires have occurred in turbine driven plants due to the oil used for lubricating purposes getting ignited. This has usually been caused by oil leakage due to the fracture of a pipe or from a badly made joint coming into contact with a high temperature steam pipe. The temperature of these pipes is quite sufficient to ignite any lubricating oils in use. Oil may leak from the bearings due to defective bearing oil seals especially if the oil pressure is high, the oil will probably escape in a very fine spray or mist in which condition it will quickly become ignited. Considerable oil may be lost in this way without notice.

Pipes carrying lubricating oil should not be run near pipes carrying high temperature steam, except where unavoidable and then a screen should be placed between the two pipes of asbestos sheet or similar material so that any leakage from the oil pipe cannot be sprayed onto the steam pipe. The pipes should also be securely braced so that there is no strain on the pipe or tendency for it to vibrate. All joints should be well made so that there is no risk of leakage or failure. Even though a connection may not leak, if it is not well made it will be liable to fail at some time. If a pipe breakage does occur, the oil leakage which will take place may not be noticed for some little time, with the result that the leakage will continue to enlarge until the oil pressure is shut off the pipe.

The felt washer or oil seals on the bearings should be maintained in perfect condition so that oil does not leak from the bearings.

Any oil leakage, however small, which is noticed should be rectified at once. Any leakage oil which may be present should be kept wiped up. Any oily waste should be disposed of so that there is a minimum of combustible material about the plant. The pressure on the lubricating system should be kept just sufficient to ensure good lubrication of all bearings, a higher pressure than this should not be used as it increases the strain on all the joints and makes leakages more likely to develop. In many instances the oil pressure must be kept higher than would otherwise be necessary owing to sharp bends or constrictions in the pipe.

An increased oil flow may be necessary to keep certain bearings cool, when the cause of their running hot may be misadjustment of the bearings, not insufficient lubrication. Under these conditions a higher oil pressure may give a partial remedy, but only at the expense of increasing the strain on the whole of the lubricating system.

Kent, England. W. E. WARNER.

Oil in Boiler Feed

ON A NUMBER of occasions I have been asked whether or not there is a device on the market that indicates directly the quantity of oil in boiler feedwater.

So far as I know, there is not. Without question such an "oil indicator" would be of much value and the inventor would do well to let the world know about it.

In view of the lack of a real "oil indicator," I should say that the most practicable way, with ordinary standard equipment, in which to determine the presence of oil, is to install a feedwater filter in the line. Place a pressure gage ahead of the filter and another behind it so that the pressure drop through the filter can be observed at all times. When clean it will be found that the pressure drop is slight. As oil accumulates in the filter cloths the pressure drop increases. A curve can be plotted between time and dirtiness, based on the pressures, which will enable one to know with surprising exactness the amount of oil in the cloths at any time after installation.

If the filter is a good one, the exact amount of oil can be determined by weighing the cloths while dirty and then when clean. The difference in weights, of course, is the weight of the oil.

Newark, N. J. W. F. SCHAPHORST.

Feed Pump Circulating Lines

I HAVE read with some interest the article by S. H. Coleman in the June, 1935, issue, "Feed pump circulating lines," and it occurred to me that the idea he describes of circulating feedwater has little to recommend it for the following reasons:

(1) The use of energy pumping water for naught.

(2) In warming up a boiler before putting it into service when no water is needed, it is cheaper to shut down the boiler-feed pump until water is needed.

(3) If the amount of water required is not enough to keep the pump casing cool and the boiler must be floated along with very little load a smaller pump or an injector should prove more economical.

(4) When boilers are banked they should be filled up to within a couple inches of the top gage glass nut, if reasonably sure that the boiler will not be called upon to meet some emergency demand. If there is a feedwater regulator, the valve should be jacked open.

I have seen cases where boiler-feed pumps were allowed to run against a closed feedwater regulator for hours, by-passing water, when the pump could have been shut down for almost an hour at a time.

Hartford, Conn. R. E. GEORGE.

Accidents Without an Excuse

COAL WAS hauled from the bunker room to a place in front of the hoppers in a small car pulled by a metal handle and this handle was dropped to the floor, in front of the car, instead of being turned underneath the car, or held upright by a hook and wire. An employee tripped over it, fell against the stoker and broke a collar bone.

An old swivel chair had a weak spring. Lots of amusement was had at the near upsets of many who sat in it, until it really did upset a man and laid him up for three weeks with a badly injured shoulder and back.

Early one morning a hotel maid relieved the service elevator operator for a few minutes. She dropped the car to the basement to pick up a house engineer, then started the car so quickly that she threw him part way out of the car and jammed his body at the first floor. Upon lowering the car to relieve the pinch he fell to the basement floor and died.

Columbus, O. B. M. LEADLEY.

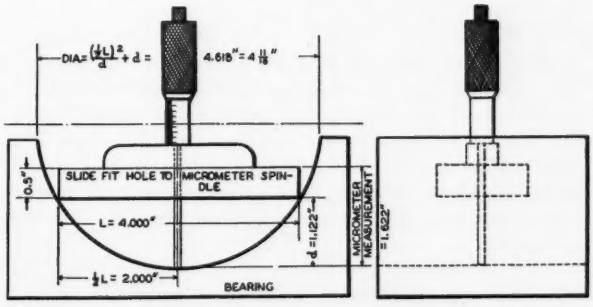
Diameter of a Circle Determined by Micrometer

WHEN it becomes necessary to obtain the exact diameter of the bore of a bearing-half whose center lies beyond the measurable part of the bore the device illustrated here and designed by myself, is very convenient.

The device consists of a prismatic plate of known dimensions, made of steel, hardened for best service, and ground to the dimensions shown. It is used in connection with a depth micrometer and a simple formula given below. As designed, it accurately determines diameters from about 4 to 6 in. Diameters over 6 in. can be closely approximated. It is, however, advisable to make another gage for the larger diameters with L 6 in. or longer. For smaller diameters make L shorter so that it enters the hole.

To measure the bore of the bearing place the gage in the bearing as shown in the illustration. Adjust the depth micrometer until its spindle just touches the bore. Take the reading to the third decimal place. Subtract the thickness of the gage from the reading, obtaining d.

$$\text{Diam.} = \frac{(\frac{1}{2}L)^2}{d} + d;$$



Finding Diameter of Bearing

Example:

Reading as obtained with the depth micrometer = 1.622 in.

1.622 — 0.500 (thickness of gage) = 1.122;

L remains constant = 4.000 with this gage.

$$\text{Then Diam.} = \frac{4.000}{1.122} + 1.122 = 4.618 = 4\ 11/16 \text{ in.}$$

which is the diameter of the bearing bore.

Highland Park, Mich. PAUL C. BRUHL.

Operating Thrills

TROUBLE developed in the boiler room of a fair sized industrial heating and process steam plant, which at the time was about 3 yr. old. The plant consisted of two 100-hp. h.r.t. hand fired boilers, and three 250-hp. horizontal water-tube stoker-fired boilers.

This battery of boilers was supplied with feedwater by a duplex reciprocating pump, the speed of which was controlled by an excess-pressure governor connected to the feedwater header, which was made up of extra heavy brass pipe and steel fittings, with a branch line to each boiler. The pressure in this line was normally about 160 lb. gage, but varied with the boiler pressure which was 150 lb. gage when we had good fires and were able to hold it there. No secondary source of feedwater supply was provided. The air supplied to the fires was natural draft.

We had just taken the watch over at 11 p.m. and everything was running along smoothly as usual, till shortly after midnight, when all of a sudden there was a crash, followed by a shower of steam and hot water, and the boiler feed pump started to run away, making a terrific noise. The pump throttle was closed as soon as possible which was none too soon.

What had happened was this, a nipple in a branch feedwater line to one of the boilers broke loose from one of the steel tee's. This reduced the pressure in the feedwater header, so that the pump governor opened wide admitting a full head of steam to the boiler feed pump allowing it to run away.

After the pump was shut down the night supervisor was called over and he decided to put a pipe plug in the open tee, cut out the one boiler and carry the load on the remaining four.

This of course was the logical thing to do but when the pump was started again the boiler feed line was found to be leaking so badly in several places, due to the shaking that it had received when the pump ran away that the only other course left was to pull all the fires, which was done without losing any time. And that was as complete a shut down as any one could wish to see. None of the boilers were damaged.

The plant engineer was called out of bed, he came in as though he were walking into a banquet hall, all smiles, gave orders and handled the situation admirably. A crew of steam-fitters had the damaged line repaired by 5 a.m. The boiler feed pump was apparently no worse off for having gone on a rampage, excepting that the concrete foundation was cracked in places.

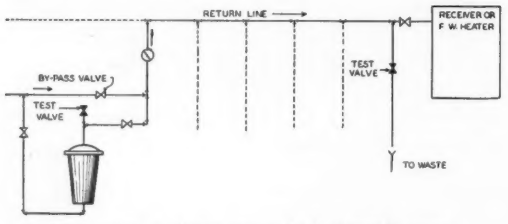
We attributed the cause of the boiler feed line failure to the fact that brass pipe was made up to steel fittings, which caused a galvanic action that slowly destroyed and weakened the threads.

After the shut down this condition was rectified and a secondary source of feedwater supply was installed.

New Haven, Conn. R. G. NORMAN.

Test Valves on Trap Return Lines

STEAM, blowing through a defective trap or trap bypass valve, is usually wasted either directly to the atmosphere or by displacing available exhaust or bled steam. To minimize this loss, test valves should be installed on each trap, as shown in the sketch. By isolating the trap from the return line and opening



Test valve to detect steam leak through traps

the test valve, any leakage is made visible and steps can be taken towards its elimination.

When a number of traps discharge into a common return line, a test valve on this line to supplement test valves on individual traps has a number of advantages. Such a valve, if opened at regular intervals, will indicate the condition of the whole return system and reduce the labor and maintenance costs incidental to checking a large number of individual trap test valves when no leakage is present.

Should leakage of steam be indicated by the return line test valve, individual traps must be isolated and tested until the faulty trap is discovered. If all traps are found to be in good condition, a leaking bypass valve is generally responsible. Care should be taken, however, not to confuse the normal flash steam from high temperature trap returns with live steam leakage.

In addition to supplying a means of determining leakage of steam into the return line, a test valve, if large enough, provides a convenient place to drain the line when it is necessary to remove the receiver or feedwater heater from service. When information regarding the quantity of returns is desired, the test valve is an ideal location for the weighing equipment.

Waynesboro, Va. S. H. COLEMAN.

Keeping Better Repair Records

IS TOO MUCH reliance placed upon memory in looking back upon power plant repair jobs? It seems so at times when occasion arises to analyze the work of equipment units, to get an idea of cost breakdowns, time spent on specific tasks and material requirements. As in all human enterprises, it is easy to overdo clerical activities bearing upon them, but there is a vast difference between preserving basic information and relying solely upon data buried in accounting department books which may never stand on a shelf under the power house roof, filling in gaps from the bare bones record of the daily log sheet.

In an eastern power system the superintendent of production writes an annual report which is bound in typewritten form every spring, covering among other things the major points involved in every important maintenance job in the generating station. All steps taken to improve the service of boilers, pumps, circulation systems, turbines, etc., are put down faithfully and the volumes of reports filed constitute an extremely interesting and useful set of reference books for staff consultation. When equipment of a pioneer character is installed, such a record not only tells the story of how the various troubles arose during the work-out period, but it reviews the changes required, if any, to maintain better service. In this case, cost data are kept elsewhere; and the repair record is built up from regular but comprehensive operating reports carried on month after month within the station offices. The task is less burdensome than might appear, thanks to these routine sources of the report.

Every plant or system must properly decide how far to carry such records for its own service, but the reward of systematic, straightforward and accessible information periodically assembled and preserved for maintenance purposes is worth consideration. Good records lift repair jobs to the engineering plane and keep them there.

Cambridge, Mass. H. S. KNOWLTON.

Why Does Brine Foam?

A DIRECT ANSWER cannot be given to the question on page 311 of the April issue without full knowledge of the system in question. However, the principal causes of brine foaming are: The giving off of air by the brine, or a recent formation of fine colloidal precipitate. Brines should be kept up to strength at all times, as weak brines will hold considerable air in solution. When large quantities of calcium chloride are added to bring the weak brine up to strength the air is forced out in minute bubbles forming a foam on the surface. Should there be any insoluble particles

due to corrosion in the system, together with the air it would form a foam which would stay on top of the brine for some time.

Corrosion might be due to the water itself, which should be tested, or by the oxidation of the metal surfaces by the entrapped air in the brine. Care should be taken to see that brine return and suction lines are kept below the surface, also that pump glands and stuffing boxes are tight, to prevent the infiltration of air. Corrosion can also take place by electrolytic action of two dissimilar metals immersed in the brine and by the leakage of electric currents not properly grounded. Excess alkalinity in brines can be corrected by the slow feeding of CO_2 gas at a point where it will be circulated without reaching the surface.

Newark, N. J. DONALD E. CHUBB.

Jet Pump Characteristics

Q. WHAT IS A water jet pump? Is it practical and efficient and where can it be used to best advantage?

K. C.

A. A WATER JET pump is a simple piece of equipment of the same general class as injectors and steam jet air pumps but possessing the decided advantage of not involving compressibility or heat transfer. The basic principle of the jet pump is the transfer of momentum from one stream of water to another. It is

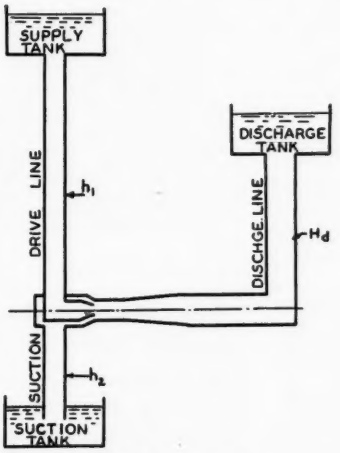


Fig. 1. Sketch of a simple jet pump

similar to an injector with water under pressure substituted for steam. A sketch of a simple jet pump is shown by Fig. 1.

This type of pump was first used by James Thomson about 1852 and the theory of pumping by jet action was developed in 1870 by Rankine. The low efficiency of this pump has limited the field of application to conditions in which the absence of valves or working parts and the small size of the unit are sufficient to offset the greater power requirements. This unfavorable circumstance has caused the water jet pump to receive less attention than it perhaps deserves.

Theory and operation of the pump are covered in considerable detail in a bulletin entitled The Water Jet Pump, by James E. Gosline and Morrough P. O'Brien, published by the University of California Press, Berkeley, Cal., and selling for 35 cents. The following test data was taken from that source.

The general shape of characteristic curves is shown by Fig. 2. The cut off point or point of maximum quantity is limited by cavitation because if the temperature of the pumped liquid exceeds the vapor pressure, the suction stream will not remain continuous. In Fig. 2 five different tests are shown with the driving pressure, h_1, varying from 43.9 to 188.7 ft. and the suction

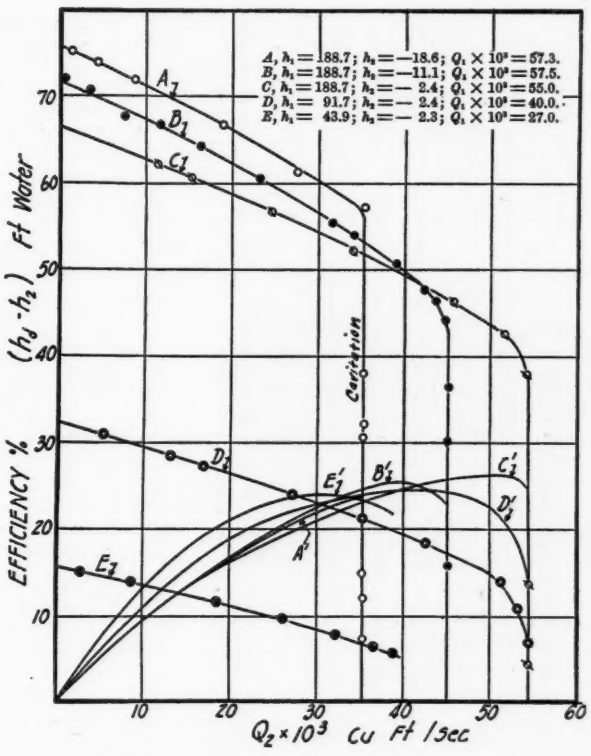

A, h_1 = 188.7; h_2 = —18.6; $Q_1 \times 10^3$ = 57.3.
B, h_1 = 188.7; h_2 = —11.1; $Q_1 \times 10^3$ = 57.5.
C, h_1 = 188.7; h_2 = — 2.4; $Q_1 \times 10^3$ = 55.0.
D, h_1 = 91.7; h_2 = — 2.4; $Q_1 \times 10^3$ = 40.0.
E, h_1 = 43.9; h_2 = — 2.3; $Q_1 \times 10^3$ = 27.0.
$(h_d - h_2)$ Ft Water
EFFICIENCY %
cavitation
$Q_2 \times 10^3$ Cu Ft /sec

Fig. 2. Characteristics of a jet pump as shown by test

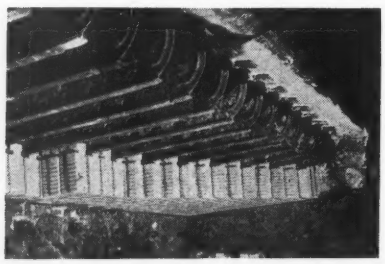
head, h_2, from —2.3 to —18.6 ft. Q_1 is the water supplied for pumping (i. e. through the drive line) and Q_2 is the quantity pumped. Although the experiments mentioned were not made to determine the effect on efficiency of modifications and design, the possibility of improvement was evident to the authors and a short nozzle with greater length of pipe or a shorter mixing chamber or its complete elimination on a smaller diffuser angle would probably have decreased the efficiency to a possible maximum of 40 per cent.

Application of the jet pump to fluids other than water merits consideration. For oil well pumping from shallow wells, after gas lift production becomes uneconomical, O'Brien and Gosline indicate the conditions under which the experimental results for water can be used. In fact they give an example based on design for oil well use. Likewise an air jet pump for mine ventilation is being developed following the suggestion that the mixing chamber be eliminated completely. Operating characteristics of this type of pump can be predicted with a high degree of accuracy and other applications are to be expected where conditions of service justify its use.

New Equipment

Suspended Arch and Wall

REFRACTORY of a new design for suspended arch and wall construction has been developed recently by M. H. Detrick Co., Chicago, Ill. The new tile are approximately one-half the size of the T-slotted tile and the faces of the tile are covered with corrugations or treads which mesh together with those on adjacent tile. The corrugations on the refractories themselves are so designed that the longitudinal joints in an arch and the



vertical joints in a wall can be either straight line or offset.

The new construction reduces spalling in two ways—first; by making the tile smaller, better molding and a more uniform burn through the interior of the tile is obtained; second; when spalls do take place, and they usually happen diagonally across the corner of a refractory, the spalls in individual tile are held in place by the corrugations on the adjoining tile and cannot fall out.

Intermeshed faces of the tile prevent leakage of furnace gases, or flames, through the refractory with a plus pressure condition and prevent air from leaking into the furnace in a draft condition. Instead of a flat sheet of fire clay or joint material that normally forms the joint in an arch or a wall, the joint in the improved construction takes the form of a waffle and the joint material is so locked in place that it cannot come loose or fall out.

Staggered joints both in the arch and the wall prevent molten slag from running along the joint and cutting it out. The fit of the treads is loose enough so that the tile take their natural alignment.

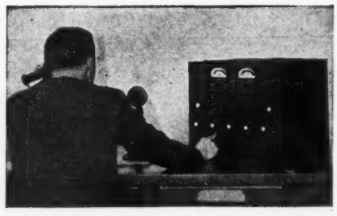
This tile is called the new Detrick Tread design, or "Detred" and will fit the existing installations made by this manufacturer without the necessity of changing the iron parts.

Low-Cost Automatic Supervisory System

A NEW 5-POINT automatic supervisory system which operates over two wires and includes the same high-quality devices that are used in large supervisory systems, is now available from General Electric. This new 5-point supervisory system provides for the complete supervision of five substation units. It permits opening and closing of circuit breakers, with indication of their position; starting and stopping of machines with indication of their conditions; the raising and lowering of speed, voltage, or gates; the obtaining of meter readings; and allows telephone conversations and calling.

Supervision, although remote, is as complete as though the operator were located at the unit to be controlled.

The supervisory equipment at the dispatcher's office consists of a control key, indicating lamps, and supervisory devices for sending selection and control impulses, and for indicating the positions of the various supervised units. The dispatcher's office equipment is com-

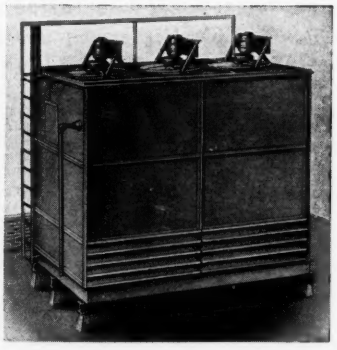


pletely assembled in a small cabinet for desk mounting. It requires the connection of only two line wires and two battery wires for complete installation.

The equipment at the outlying station consists of the supervisory devices which transmit the control impulses to the auxiliary control relays and send back checking and indicating impulses to the dispatcher's office. This substation equipment is assembled in a case designed for panel mounting. It is equipped with numbered terminals for connecting two battery wires, two line wires, and breaker control and indication circuits.

Induced Draft Cooling Towers

BINKS MANUFACTURING Co., Chicago, Ill., announced a new line of induced draft cooling towers with a cooling capacity ranging from 5 to 200 g.p.m. These new type towers are recommended for refrigeration plants having from 1 to 50 t. refrigeration capacity for internal combustion engine jacket water cooling, and other industrial appli-



cations. The nozzles spray a finely atomized mist of water downward through upward currents of air induced by the fan assemblies placed at the top of the tower. During cool weather, the fans may be shut off and ample cooling capacity secured without their use.

Depending upon tower size and capacity, one or more fans are used, the fans being driven by individual splash and weather proof motors at speeds of approximately 450 r.p.m. All towers of the type K series are constructed of heavy steel frame surrounded by a sectional copper-bearing galvanized steel housing asphalted and aluminum painted inside and out before shipment.

Gruv-Seal Forged Iron Ring Gasket

UNDER THE NAME "Gruv-Seal," The Steel Improvement & Forge Company, 960 Addison Road, Cleveland, Ohio, is marketing a line

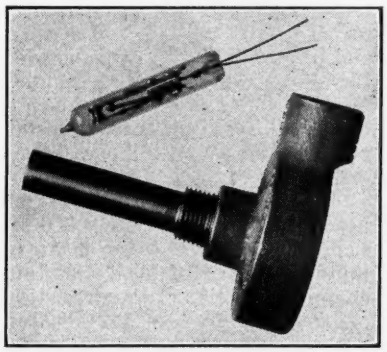
of forged iron ring gaskets for grooved joints in sizes from 2½ to 14¾ in.

Gruv-Seal ring gaskets are designed especially for high pressure and high temperature lines, wherever bolted joints are effected with grooved flanges, and where ready disassembly is a requirement.

Drop forged and pressed in a coin die, the rings are proportioned so that they fit the groove at all points. The iron of which they are made maintains a pliability that seals the connection when the bolts are drawn tight, yet retains the inherent stamina of forged metal to withstand strains due to expansion and contraction. In addition the metal has corrosion resisting properties which qualifies the ring gaskets for many uses.

Temperature Control for Diesels

TEMPERATURE CONTROL for use on water cooled internal combustion engines is announced by Edison Electrical Controls Division of Thomas A. Edison, Inc., West Orange, N. J. The Edison sealed temperature control which forms the nucleus of the device is completely sealed in a glass tube from which the air has been evacuated and replaced by an inert gas to prevent the contact points from oxidization or pitting by repeated operation. Loss of calibration due to continuous operation or tampering by an inexperienced person is not possible.

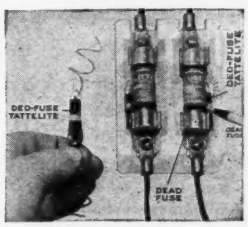


The temperature control for engines, catalog M6-D8, consists of this sealed control mounted in a metal tube provided with a standard pipe thread and a suitable junction box for electrical connections. It may be used to protect engines in several ways. It may be mounted in the cooling water of a Diesel engine (1) to signal an attendant when a predetermined temperature is reached; (2) to stop the engine when the temperature approaches a dangerous degree; or (3) to hold the temperature of the water constant by varying the flow.

In gas engines it may regulate the flow of water or it may cut off the ignition by opening the primary of the ignition coil or by grounding the magneto. It is also used on supervised gas engines to sound an alarm. In both gas and Diesel engines the control will operate when a predetermined temperature is reached, whether the temperature is caused by low water in the cooling system, lack of proper lubrication, or similar reasons.

Ded-Fuse Tattelite

DED-FUSE TATTELITE is the name of a tiny neon lamp and casing, designed to tell instantly when and where a fuse is blown. The lamp bulb itself is only the size of a pencil tip 1 in. long. These fuses connect directly in parallel with the fuse and draw no current until the fuse has blown. They are adapted for use on any size cartridge fuse, and even plug fuses, since they measure only 1¾ in. long overall by 5/16 in. maximum diameter and have 6 in. connecting leads. They are designed for circuits of 100 to 550 v. a.c. or d.c. and light on only .0005 amp. current. A protective resistance is built in. Other uses are indicating open circuits, switches, relays, etc.



They are made by the Littelfuse Laboratories of Chicago.

Nicholson Traps

STYLE "AU" and Style "C" are the names used to designate two new models of steam traps recently introduced by W. H. Nicholson & Co. of Wilkes-Barre, Pa. The Style "AU," with a union connection and of bronze construction, is adaptable for use on radiators and unit heaters where reduced high pressure steam is used. In event the reducing valve should stick, or get out of adjustment, and the pressure increases up to as high as 150 lb., it will not damage the bellows element of this trap.

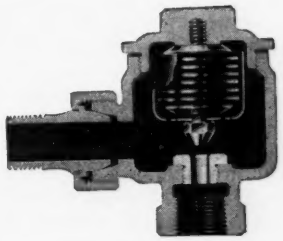


Fig. 1. Type AU

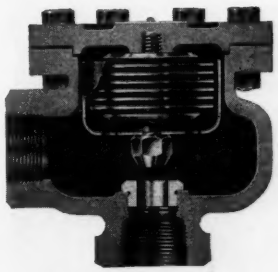


Fig. 2. Type C

The bellows are made from phosphor bronze tubing hydraulically formed, and with end plates brazed on and not soldered, which accounts for its ability to withstand high pressures and temperatures.

Style "C" is of cast-iron construction and good for pressures up to 200 lb., and made in angle type so the trap drains itself when steam is turned off. This feature is desirable on outside installations as it prevents freezing. This trap also has the brazed bellows element as described above, which gives it an intermittent discharge and ability to handle large quantities of both water and air. Valves and seats are of hardened stainless steel.

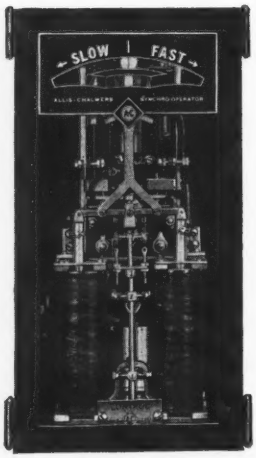
Synchro-Operator

THE ALLIS-CHALMERS Manufacturing Company, Milwaukee, Wisconsin, has placed on the market the "Synchro-Operator," an automatic control device, which eliminates all human element and performs rapidly the combined functions of speed matching, synchronizing and visual phase angle indicating; these formerly required a frequency matcher, an automatic synchronizer and a synchroscope.

The "Synchro-Operator" is not much larger than the usual synchroscope and can be mounted on a swinging bracket.

It accurately synchronizes generator and bus even if there is a voltage difference and it is satisfactory for both stable and erratic frequencies. The control closing instant is advanced (at a phase angle proportional to the difference in frequency) to compensate for the inherent time lag in circuit breakers, thus making the breaker close at the exact point of synchronism.

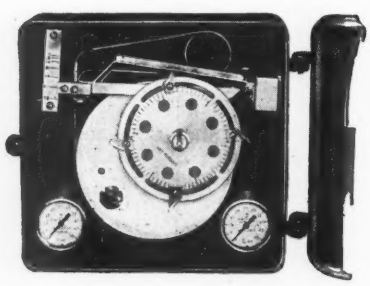
One "Synchro-Operator" will serve any number of generators and can be used in connection with existing governor control motors and station circuit breakers. It



consumes little energy, operates through standard potential transformer metering circuits, requires no special features on prime mover or generator and contains no vacuum tubes.

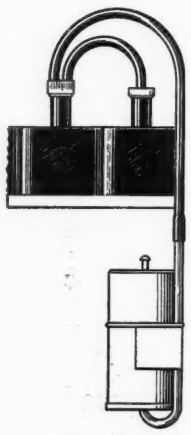
Taylor Intermitter

HEREWITH is the illustration of the Taylor Intermitter which was inadvertently omitted from the description of the instrument in the July issue, page 424. By reference to the description, the reader can see the simplicity of its design.



Air Bell

DESIGNED to replace the rubber air bag on the Orsat type of gas analyzer, an air bell is announced by the Ellison Draft Gage Co., Chicago, Ill. It consists of a floating bell in a cup filled with water up to the bead. The weight of the bell



provides the necessary air pressure which is constant for the full range of the bell movement. The bell is connected with the solution containers with ⅛ in. bore rubber tubing. The bell assembly and fittings are of brass, nickel plated.

Device Tests Ageing Characteristics of Oils

A new device known as the Oxydator has been developed which is used for the purpose of investigating the aging qualities of various kinds of oils, transformer oils, lubricating oils, insulating varnishes, etc. The "Oxydator" produces the aging effect on oils and other materials by applying oxygen under carefully standardized conditions. It permits definite, reliable measurements of the quantity of oxygen which a material absorbs during a definite period. The larger the quantity of oxygen which a material will absorb and the greater the speed at which such absorption takes place, the quicker the material will age in its practical application, and the smaller will be its resistance to deterioration. Both, the quantity of oxygen absorbed and the speed of this absorption for a material under test, are clearly shown by a characteristic "ageing curve" which can be plotted on basis of the test data obtained by means of the "Oxydator."

In the Oxydator the oil or other liquid to be tested is poured on a calibrated catalyzer and is exposed to the action of oxygen at a temperature of 100 deg. C. The oxygen is produced in the apparatus itself, in the same quantity as absorbed by the material under test. The electrical current required to produce this quantity of oxygen, is measured, and the data thus obtained represent an exact measure of the "oxidability" of the material investigated.

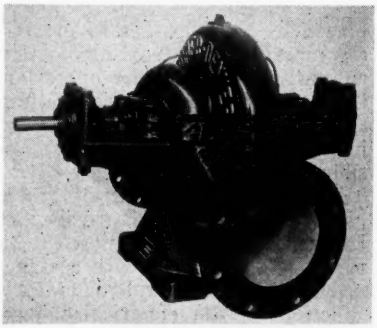
In ordinary methods of test, the data obtained is limited to the particular condition of an oil as established at one definite, arbitrary moment. With the Oxydator, a curve is obtained showing the entire process of oxidation against time. In considering the so-called "sludge" test for oils, the Oxydator it is claimed reveals directly the condition the sludge test indicates indirectly. "Sludge" is formed in consequence of the oxidation of the oil.

The test period for obtaining a complete ageing curve is 100 min., but for a simple analysis 30 min. are sufficient. The quantity of oil required for one test is 15.5 grams. The Oxydator is being marketed by Herman A. Holz, New York, N. Y.

New Line of Pumps Introduced by Gardner-Denver

GARDNER-DENVER Co., Quincy, Ill., announces a new line of double suction, single-stage split case centrifugal pumps which is adaptable to practically any class of service, and is particularly recommended for general water supply in municipalities, industrial establishments, office buildings, and similar installations, due to their compactness and high efficiency.

This series of pumps covers all heads up to approximately 300 ft., each type of pump covering a certain percentage of head and thus enabling selection of the exact type of pump for any head up to 300 ft.



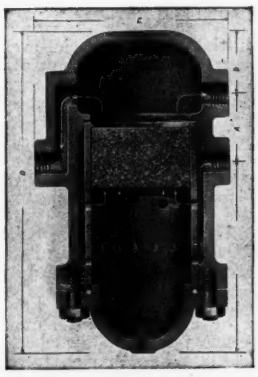
Considerable attention has been given to making the pump easy to maintain, everything possible being done for the convenience of the operator. The shaft sleeve nut, for example, is located outside the pump and next to the pumping housing, a convenience in tightening sleeves. This nut is also used as a jack to remove the ball bearing, no puller is required.

The bronze impellers are of double suction enclosed type, hydraulically balanced.

The casing itself is of cast iron design and is split on the horizontal centerline to permit access to the pump interior without disturbing the suction or discharge pipes.

Process Air Filters

FOR REMOVING MOISTURE, oil and other foreign matter where dry, clean air is required for process work, the Marshalltown Mfg. Co., Marshalltown, Iowa, announces the development of a new air filter. The body of the filter is of cast iron and the retaining cylinder holding the filter stone is of acid resisting bronze. The filter stone, which operates with only a slight loss of pressure, removes moisture and impurities and is readily cleaned by immersion in any oil solvent such as naphtha, benzine or carbon

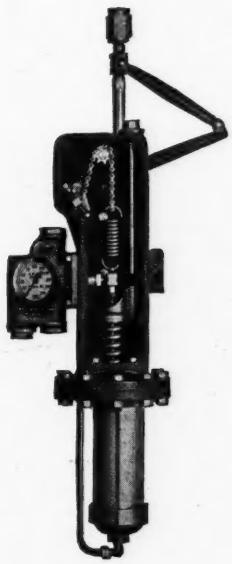


tetrachloride. An extra stone is supplied with each filter and the unit may be installed on either horizontal or vertical pipe lines.

The filter should be installed on a cool line close to the point of application. Entering air comes in contact with the retaining cylinder and condensation drains to the chamber at the bottom. Air then enters through a number of small holes in the retaining cylinder and passes up through the filter stone as shown by the arrows in the illustration. The filter is built in five sizes ranging from ½ to 2 in. with capacity range (at 100 lb. pressure with loss of less than 1 lb.) of from 20 to 240 c.f.m. of free air.

New Cash Controller

NEW WITH A. W. CASH CO., Decatur, Illinois, is the Type 100 Series of controllers each of which is a self-contained unit comprising (1) an actuating member, diaphragm or lever, (2) a four-way control valve which governs the flow of water, oil, or air to (3) a double acting power cylinder built



into the unit as an integral part, (4) a built-in compensator and (5) a simple range adjustment.

The pressure responsive (or actuating) member may be a diaphragm with the controlled pressure on one side, a diaphragm with the controlled pressures on both sides, or a lever which is moved by some outside or remote means. The purpose is to operate balanced valves, chronometer valves, butterfly valves, dampers, regardless of size; to operate electric rheostats, stokers, pulverizers, fans, and other apparatus driven by engines, turbines or electric motors; the objective is the automatic control of the factors of combustion; automatic fluid pressure control reduction, regulation, or relief; back pressure control; rate of flow control, or liquid level control.

They are extremely sensitive because of the steps taken to eliminate friction, i.e., frictionless diaphragm bearing, frictionless and leakless packing and four-way valve, and the suspension of the spring load in such a manner that side strains on the valve lever are eliminated. The compensator works so that a given percentage of change in the pressure under control will result in an equal percentage of change in the output of the apparatus under control. The entire mechanism is protected by a dust proof cover.

Electrical Engineers Elect Officers

E. B. MEYER, chief engineer, Public Service Electric & Gas Company, Newark, N. J., was elected president of the American Institute of Electrical Engineers for the year beginning August 1, 1935, as announced at the annual meeting of the Institute held at Ithaca, N. Y., during the annual summer convention of the Institute. The other officers elected were: Vice-Presidents W. H. Harrison, Philadelphia, Pa.; Mark Eldredge, Memphis, Tenn.; R. H. Fair, Omaha, Neb.; N. B. Hinson, Los Angeles, Calif.; C. V. Christie, Montreal, Canada.—Directors C. R. Jones, New York, N. Y.; W. B. Kouwenhoven, Baltimore, Md.; G. C. Shaad, Lawrence, Kans. —National Treasurer W. I. Slichter, New York, N. Y. (reelected).

These officers together with the following hold-over officers will constitute the Board of Directors for the next administrative year, beginning August 1, 1935: J. Allen Johnson (retiring president), Buffalo, N. Y.; J. B. Whitehead, Baltimore, Md.; F. O. McMillan, Corvallis, Ore.; F. J. Meyer, Oklahoma City, Okla.; G. G. Post, Milwaukee, Wis.; R. H. Tapscott, New York, N. Y.; W. H. Timbie, Cambridge, Mass.; F. Malcolm Farmer, New York, N. Y.; N. E. Funk, Philadelphia, Pa.; H. B. Gear, Chicago, Ill.; P. B. Juhnke, Chicago, Ill.; G. A. Kositzky, Cleveland, Ohio; Everett S. Lee, Schenectady, N. Y.; A. H. Lovell, Ann Arbor, Mich.; L. W. W. Morrow, New York, N. Y.; A. C. Stevens, Schenectady, N. Y.

The annual report of the Board of Directors, presented at the meeting, showed a total membership on April 30, 1935, of 14,253. In addition to three national conventions and two District meetings, 1,507 meetings were held during the year by the local organizations of the Institute in the principal cities and educational institutions in the United States, Canada, and Mexico.

News From the Field

UNITED STATES RUBBER PRODUCTS, INC., Pittsburgh, announces the appointment of Arch Miller as Packing Representative for the Pittsburgh District.

ERNST WATER COLUMN & GAGE CO., Newark, N. J., announces the appointment of MacDonald Sales & Engineering Co., 6312 Sherwood Rd., Philadelphia, as representative for Philadelphia and Baltimore district, also H. C. Hartmann, 3617 Winnebago St., Saint Louis district representative.

FRICK Co., Waynesboro, Penna., announces the appointment of Henning N. Borgstedt as manager of its branch office in New York City.

STANDARD FUEL ENGINEERING Co. of Detroit, Michigan, announces the appointment of the E. B. Packard Co. of 30 Church St., New York City, as sales representative of refractory cements and allied refractories in the New York territory.

DATA BOOK No. S-20, published by the Smoot Engineering Corp., 2240 Diversey Parkway, Chicago, Ill., describes the Smoot system of control applied to boilers, and also contains a concise discussion of the basic problems of boiler operation and an evaluation of their importance in the final result, efficient steam generation. Basic problems, the difference between control of systems and simple regulation, essentials of successful mechanical control systems are discussed and numerous diagrams illustrating mechanical control applied to various types of boilers and fuel firing equipment are shown.

COMBUSTION ENGINEERING Co., Inc., 200 Madison Avenue, New York, announces the appointment of E. R. Shequine as New York District Manager, Industrial Stoker Division, in charge of the sale of the Combustion line of stoker-units in the New York Metropolitan and Northern New Jersey districts.

INTERNATIONAL NICKEL Co., Inc., has added to its research staff O. W. McMullan, formerly chief metallurgist at the Timken-Detroit Axle Co. and before that with Studebaker Corp. He is a graduate of University of Michigan and author of many papers on metallurgy. To the field staff has been added Harold L. Geiger, with special training on problems of steel mills and the machining and treatment of steels, gained with Inland Steel Co. and as chief metallurgist of Wisconsin Steel Co. Mr. McMullan will be in the Bayonne laboratory and Mr. Geiger will work from the Detroit office and later from New York City.

THE KENNEDY VALVE MANUFACTURING Co. announces the appointment of Thomas C. Swope as Texas and Louisiana representative, with headquarters at Beaumont, Texas.

THE BABCOCK & WILCOX Co. announces that J. W. Barnett, recently Director of the Division of Construction and Finance of the U. S. Shipping Board will, on July 1, become associated with the company's marine department.

L. A. S. WOOD, chief lighting engineer, Westinghouse Electric & Manufacturing Company was elected President of the Illuminating Engineering Society for a twelve-month term beginning October 1, 1935. Mr. Wood has been closely identified with the lighting industry ever since he began his business career and is thoroughly familiar with lighting practice not only in this country, but also in England, of which country he is a native. His association with the electrical industry comes naturally, as his grandfather was one of its pioneers and was associated with Michael Faraday in his research work at the Royal Institute, London.

THE OSBORN MACHINE Co. of DuBois, Penna., announces the opening of a Pittsburgh Sales Office, 820 Empire Bldg., with C. K. Wehn, recently appointed General Sales Manager, in charge, also the appointment of James J. Zimmerman as Works Manager.

DR. IRVING LANGMUIR, associate director of the General Electric Research Laboratory at Schenectady, has been elected to foreign membership in the Royal Society, England. Foreign membership, considered one of the highest honors that can be bestowed by British scientists on fellow workers in other countries, is limited to fifty persons throughout the world. Dr. Langmuir, Nobel prize winner, is one of the eight Americans now foreign members of the Royal Society, and is the only American industrial scientist so honored.

ANNOUNCEMENT has recently been made of the formation of a new company to be known as the Buell Engineering Co., Inc., 70 Pine St., New York, N. Y. The activity of this company will be the manufacture of the Buttner Drying Systems of the rotary, turbo and fine-film types as well as the Van Tongeren System of dust extraction for fly-ash from stack discharge, as well as from the collection of dust from chemical and cement plants. In addition to these products, burners and pulverizing sets for power and industrial grinding will be manufactured.

The Buell Engineering Co. will be associated with the Struthers-Wells-Titusville group and the Buell Combustion Co., Ltd., of England, and thereby with the New Consolidated Gold Fields. Officers of the Buell Engineering Co. including its Board of Directors, consist of H. S. Emlaw and F. C. Baker, directors of Gold Fields American Developments, S. H. Mezies, representing the English interests, and T. J. Dillon, of the Struthers-Wells-Titusville Corp.

FREDERICK N. CONNET, inventor of automatic registering devices used with the Herschel-Venturi tube, died at Providence, R. I., on June 18 after an illness of five yr. He was born at Flemington, N. J., in 1867 and after graduating as a mechanical engineer from Stevens Institute of Technology, Hoboken, N. J., entered the employ of the Builders Iron Foundry, at Providence. Here he gradually advanced until he attained the post of chief engineer, which he held until his retirement in 1930 on account of poor health. Outstanding among his inventions was the device which integrated the rate of flow into total quantity in the Venturi tube, which made this apparatus practicable for world-wide service and gained Mr. Connet the John Scott medal of the Franklin Institute in conjunction with his co-worker, W. W. Jackson. In 1907 Mr. Connet obtained patents on a pioneer flow controller operated by a contraction in a pipe line, extensively used in filtration plants. Other inventions included a feedwater regulator, variable speed drive chemical feed, meter for viscous oils, valves, belt shifter, and grinder.

LINK-BELT Co. announces the appointment of Henry A. Petter Supply Co., of which the head is Stanley D. Petter, Paducah, Ky., as distributors of Link-Belt crawler-mounted shovels, cranes, drag lines and track-type locomotive cranes.

LOUIS H. BRENDEL has joined the Consolidated Ashcroft Hancock Co., Bridgeport, Conn., as assistant sales manager of the Hancock Valve Division. He will assist M. S. Palmer, sales manager.

W. S. LONG, formerly Manager Mechanical Sales of the United States Rubber Products Inc. in the Seattle District, has been transferred to the Los Angeles District as Manager Mechanical Sales at that point, and C. W. Gilmer, formerly salesman in the San Francisco District, has been appointed Manager Mechanical Sales, Seattle District. Announcement is also made by the United States Rubber Products Inc. that its New Orleans Branch has been moved from 202 Fulton St. to 440 Canal St.

STEPHENS-ADAMSON MFG. Co. of Aurora, Ill., announce the appointment of L. R. Veatch to handle sales and engineering of Redler conveyors in Buffalo, N. Y. and surrounding territory.

JOHN G. BARRY, senior vice-president of the General Electric Company, after more than 45 years with the company, has retired from active service and has been elected to an honorary vice-presidency, as announced by President Gerard Swope. Mr. Barry, as active head of the apparatus sales organization, has for many years formulated and executed the company's policy and sales program in the apparatus field. He will maintain an office in Schenectady and will be available for consultation. The retirement was effective as of July 1.

WILLIAM H. POWELL, Engineer-in-Charge of Direct Current Design, Allis-Chalmers Mfg. Co., Milwaukee, died at his home in Wauwatosa on July 8th. Mr. Powell was born in England, educated in the public schools of New Britain, Conn., and graduated from Cornell University in 1890. In September, 1904, Mr. Powell went as an Electrical Engineer to the Bullock Electric Mfg. Co., Cincinnati, Ohio, which had just become affiliated with the Allis-Chalmers Co. of Milwaukee. He served as Superintendent of the Bullock Works from 1904 until late in 1908 when he moved to Milwaukee. Mr. Powell is perhaps best known as the inventor of the Frog-Leg Winding, which greatly improved commutation in direct current machines.

SARCO COMPANY, INC., 40 East 34th St., New York, is planning to equip a new factory with machinery for the production of steam traps and temperature control apparatus. T. Nappier Adlam, Chief Engineer, will select equipment.

For the Engineer's Library

THE DIRECT SEPARATOR CO., Inc., Syracuse, N. Y., has just issued catalog EJ-35 dealing with direct internally and externally guided expansion joints. In addition to giving rather detailed descriptions of these joints, the catalog contains tables of sizes and list prices for the types available.

M. H. DETRICK CO., 140 S. Dearborn St., Chicago, has just issued a 16 page bulletin illustrating and describing the new Detred construction of water walls and arches.

DEEPWELL TURBINE PUMPS are described in the booklet W-450-B17A of the Worthington Pump & Machinery Corp., Harrison, N. J. Cross-sectional views show details of construction, tables give sizes and capacities and the text tells of the applications of this type of pump to such work as: irrigation, de-watering of cofferdams and mines, process circulating and unloading of liquid shipment cargoes.

JULIEN P. FRIEZ & SONS, INC., Baltimore, Md., has issued its bulletin No. A illustrating and describing Friez instruments for the automatic control of humidity, and other instruments used in the process of air conditioning.

IN CELEBRATION of its 25th year in the production of refractories The A. P. Green Fire Brick Co. of Mexico, Mo., has issued a Silver Anniversary booklet containing a brief history of the institution, photographs of various departments and equipment in the plant, leading personnel in the organization and group activities of employees.

THIRD EDITION of the Timken Engineering Journal has just been issued by The Timken Roller Bearing Co., Canton, Ohio. Copies may be secured without charge by engineers, designers, libraries, and executives on request to the company, written on company stationery, giving title or connection.

This 260 page book is a series of 8½ by 11 in. loose leaves, bound in a heavy three ring binder with stiff covers, with a 22 section marginal tab index for ready reference as well as the customary detailed index sheet.

The first 46 pages cover the design of Timken Bearings with illustrations of the various types, a discussion of how they are rated, the curves and factors which apply for speed, life expectancy, engine torque, use or application, also 15 typical examples of how loads are calculated and bearings selected.

This Third Edition of the Journal includes 54 new standard bearings and a new series of 6 heavy duty thrust bearings. Numerous minor changes in bearing construction, tolerances, etc., have been made and certain revisions of drawings to bring them up to date.

Supplementing the Journal are seven special sections on: mine cars, conveyors, shop trucks, cranes, aircraft, machine tools, and farm equipment. The first five give detailed bearing recommendations for the particular applications.

COMBUSTION ENGINEERING CO., Inc., 200 Madison Ave., New York, has issued a bulletin giving full information on all essential boiler and setting dimensions for the numerous sizes of V M boilers within the range between 1359 and 6300 sq. ft.

THE NEW CONVECTOFIN HEATER BULLETIN, designated as No. 8, is a 12-page 2-color publication on the built-in heater, manufactured by the Commodore Heaters Corp., 11 West 42nd St., New York, New York, for all kinds of room heating. Dimensions of heaters are given, together with features of practical value in designing and installing piped-up heating systems.

THE HAYS CORPORATION, Michigan City, Ind., has just published its catalog PGA-35, covering the company's complete line of dry type pointer draft gages, inclined tube, direct reading, U-tube and vernier scale gages, and dry type draft recorders.

CHAIN BELT CO., Milwaukee, Wis., has issued a catalog designated as Bulletin No. 260, which shows in picture form the various types of material handling equipment that the company manufactures, and its application in certain specific industries.

"PHYSICAL PROPERTIES of Speed Portland and Blended Cement Mortars and Concretes" is the title of an engineering bulletin recently published by Purdue University as Research Series No. 47. This bulletin is a report of the investigation conducted by the engineering experiment station in coöperation with The Louisville Cement Co., prepared by R. E. Mills and R. B. Crepps. It reports data of the more important physical properties of mortars and concretes manufactured from both the normal Portland cement and the blended cement. The physical characteristics of the cements have been studied in an extensive series of comparative tests involving strength (tension, compression and flexure, plastic flow, resistance to fatigue, expansion and contraction, durability, etc.).

NICKEL CAST IRON DATA is the title of a bulletin which gives the properties of nickel alloy cast irons and their special applications. It covers the effect of nickel on gray iron as to structure, machinability, wear and strength. Copies may be had on request from The International Nickel Co., Inc., 67 Wall St., New York, N. Y.

W. H. NICHOLSON & Co., Wilkes-Barre, Pa., under the title Nicholson Welded Steel Float and Welded Stainless Steel Float, has issued its bulletin No. 635, describing the construction and giving prices, weights and buoyances of the various designs and sizes manufactured.

FRICK CO., Waynesboro, Pa., has issued its bulletin No. 504-A entitled Air Conditioning with Frick Refrigeration. The bulletin consists principally of illustrations showing the application of refrigerating equipment in theaters, restaurants, hotels, shops, department stores, office buildings and industrial plants.

PROPOSED STANDARD for large rivets, ½ in. nominal diameter and larger, has been completed by the Subcommittee on Standardization of Bolt, Nut and Rivet Proportions of the A.S.M.E. and is now being distributed to the industry for criticisms and comment. Copies can be had by writing C. B. Le Page, Assistant Secretary, A.S.M.E., 29 W. 39th St., New York.

C. J. TAGLIABUE MFG. CO., Park and Nostrand Aves., Brooklyn, N. Y., has issued bulletin No. 1117, fully describing the entire line of TAG diaphragm valves and giving complete dimensions as well as instructions for sizing valves.

FIVE NEW FOLDERS issued by Caterpillar Tractor Co. of Peoria, Ill., deal with the following applications of Diesel power units: Diesel-electric generating sets; flour, feed and saw mills; pumping installations and gravel plants; and a diversified list of machines such as excavators, cotton gins, industrial locomotives and in plants.

INDUSTRIAL compressors and vacuum pumps, designated as Type 30, ¼ to 15 hp., pressures up to 1000 lb. are covered in a new catalog (Form 7502-D) by Ingersoll-Rand, 11 Broadway, New York City. The compressors described include single-stage, single and twin-cylinder, and two-stage machines. Either automatic start and stop or constant speed control is used, depending upon the type of service.

LOUISIANA STATE UNIVERSITY PRESS, Baton Rouge, La., has just published a bulletin entitled Dissolved Oxygen in Boiler Feedwater, prepared by M. C. Schwartz, Ph.D. and designated as University Studies No. 21. This bulletin is divided into two sections, the first on the determination of dissolved oxygen, enumerating the reagents necessary and the technical procedure. The second section is a selected bibliography on the determination of dissolved oxygen in water dating from 1908 up to and including 1934.

CARBONDALE MACHINE CORP., Harrison, N. J., has issued its bulletin No. 1100 which covers a line of horizontal single and duplex refrigeration compressors, of the single stage and two stage types, steam driven and motor driven. The bulletin also contains a detailed discussion of the construction features together with dimension tables of various types of units.

FELT PRODUCTS MFG. CO., 1508 Carroll Ave., Chicago, has issued its catalog No. 243 dealing with mechanical packings of the metallic and fibrous types.

BINKS MANUFACTURING CO., 3114-40 Carroll Ave., Chicago, announces the publication of a new 8-page, 2-color, Spray Nozzle Bulletin known as No. 50. The publication contains complete spray nozzle data and selection charts for all principal applications in the industrial field, including nozzles for air conditioning, water cooling and water washing work, brine spray refrigeration, spray drying, moistening, air humidifying, and hundreds of other industrial applications.

THREE TYPES of high temperature bonding mortars—Thermolith (with a chrome ore base), Firebond (with a silica base), and Harwaco Bond (with a diaspore base) are described in folders recently issued by Harbison-Walker Refractories Co., Pittsburgh, Pa. In addition, each folder contains a list of applications for which the bonding mortar described is suited and is being used with economy.

Photo courtesy Bureau of Reclamation

Big Coulee Dam Under Construction

LOOKING DOWNSTREAM from the east abutment of Big Coulee Dam. At this point the Columbia River flows due north for a short distance before swinging around to begin its sweep to the junction with the Snake 100 mi. south. The development on the opposite bank is Engineers' City while that in the right foreground is about half of Mason City. The original low dam contract, scheduled for completion about 1937, was recently modified to eliminate the power plant structure and will serve only as a foundation for the high dam. The contract for the high dam will amount to about seven times as much as the foundation contract and will probably be advertised this year. The finished dam will include the power plant structure and will back the water up about 151 miles to the Canadian border. The proposed ultimate capacity will amount to 1,780,000 kv-a. and the turbines will operate under a maximum head of about 365 ft. About 1,200,000 a. will be brought under irrigation later.

THE LAWRENCE MACHINE & PUMP CORP., 371 Market Street, Lawrence, Mass., has issued Bulletin 201 covering double suction, horizontally split pumps. It describes thoroughly the construction of pumps of this type, their possible applications, and indicates the range of capacities and heads for the different sizes.

VOCATIONAL TRAINING for the Pulp and Paper Industry is the title of Bulletin 168 issued by the Federal Board for Vocational Education, Washington, D. C. It is for sale by the Supt. of Documents, Washington, D. C. at 20c. This is a 6 by 9 in., 245-page paper bound book prepared in conjunction with the Technical Assn. of the Pulp and Paper Industry as a job analysis with suggestions on the organization and operation of training programs. It is divided into three parts: Part 1 dealing with the manufacture of pulp and paper developments and training problems involved; Part 2 lists the various jobs, what the operator should know, the source of information for training purposes and the method of training used; Part 3 is devoted to the training of the personnel, information available and illustrations showing how the material may be used in breaking in new men on the job, improving regular workers and improving personnel by organized instruction.

BULLETIN No. 102 of the Bailey Meter Co., Cleveland, O., is a 31-page booklet describing in detail the air operated combustion control system of that company. Advantages of automatic combustion control, diagrammatic drawings of different arrangements, photographs of the equipment and typical installations are shown.

HORIZONTAL DUPLEX piston pumps for general service for pressures up to 200 lb. per sq. in. are described and illustrated in a 6-page pamphlet W-102-B1 of the Worthington Pump & Machinery Corp., Harrison, N. J.

A DIESEL MANUAL edited by A. D. Newell is being distributed by the Diesel Publications, Inc., New York City. This is a 4 by 6 in. paper bound volume of 89 pages dealing primarily with Diesel operation.

PRINCIPLES OF MOTOR FUEL PREPARATION AND APPLICATION, VOLUME I. By Alfred W. Nash and Donald A. Howes. Published by John Wiley & Sons, Inc., New York, N. Y. Size 6½ by 10 in., 507 pp., cloth bound. Price $8.00.

Development of the internal combustion engine may perhaps be looked upon as one phase of the most remarkable of all industrial achievements, the coordinated efforts of geologist, engineer, chemist and business man in the production and utilization of petroleum and petroleum products. In this age of startling progress few branches of technology can equal the progress made in the production of fuels for this type of engine. Old tests and values are no longer adequate and new terms and tests, anti-knock valves, ignition qualities and gumming tendencies are now of prime importance.

It is extremely fortunate for the Diesel engineering profession that a work of this kind has been undertaken by men with an adequate knowledge of the field and ability to present such a complex subject in a readable and understandable manner. Volume I deals with the production of motor fuels by methods of distillation, cracking, extraction from natural gas and hydrogenation, with auxiliary chapters on benzol, alcohol, blended and synthetic fuel, storage and distribution. The book covers a phase of engineering so intimately connected with all industries and of such wide interest to industrial engineers that it warrants a space on all bookshelves, especially on those where a modest budget makes it imperative that each book serve a useful purpose.

THEORY OF ALTERNATING CURRENT WAVE FORMS. By Philip Kent. 5½ by 8¾ in., 228 pages, 73 figures, cloth. Published by Instruments Publishing Co., Pittsburgh, Pa., 1935. Price $4.50.

The book is Volume I of a series of monographs on Electrical Engineering now in preparation under the editorship of H. P. Young, head of the Electrical Power and Machinery Sections of the Polytechnic at London. The aim of this series is to enable engineers, advanced students and others to obtain authoritative works on special and imporant subjects which are either ignored or inadequately dealt with in standard textbooks. The author of each monograph has achieved eminence in his chosen field and thus writes with intimate knowledge of his subject. Philip Kemp, the author of this first volume of this series, is head of the School of Engineering at The Polytechnic at London. His qualifications to present a book on the subject of Alternating Current Wave forms are amply reflected in the book itself. It is fundamental, thorough and is presented as simply as such a complex subject permits.

In the study of alternating current theory it is but natural that the subject should be approached from the standpoint of the simple sine wave. The sine wave treatment however, is only an approximation to the actual truth and for a proper understanding of alternating current phenomena it is necessary to study the properties of non-sinusoidal waves. This book is an attempt to place before the reader those facts relating to non-sinusoidal waves which are necessary for a proper understanding of the subject, a general knowledge of alternating current theory being assumed. The subject is treated generally without reference to specific machines on types of apparatus but it is hoped to include such matter in a later volume. Chapters I and II are devoted to Properties of Complex Waves; Chapter III deals with the effect of iron; Chapter IV The Effect of other Conditions; Chapter V Harmonics in Polyphase systems and Chapter VI Harmonic Analysis.

ELEMENTS OF STRENGTH OF MATERIALS. By S. Timoshenko and Gleason H. Mac Cullough. First Edition, 350 pages, 6 by 9 in. cloth, illustrated. Published by D. Van Nostrand Co., Inc. New York, 1935. Price $3.25 net.

This textbook on strength of materials is an outgrowth of Timoshenko's "Strength of Materials." Whereas the latter work, published in two volumes, presents both the elementary and advanced aspects of the subject, the present work is designed

primarily as a textbook for undergraduate courses in strength of materials in our American colleges and schools of engineering.

In this abridged edition, a constant effort has been made to retain the principal features of the larger work and, at the same time, to present the material covered in a way conforming to American methods and preferences. Some material has been rearranged and rewritten with the hope of making it even more teachable.

Fundamental principles are emphasized and the student is encouraged to go back to these fundamentals in his study of the subject rather than to depend upon blind substitution in formulas. A large number of problems for student solution has been included together with the necessary illustrative problems. The notation in general agrees with that recommended by the American Engineering Standards Committee.

It is difficult in a brief notice of such a book as this to indicate its contents but a list of the chapter headings may be of assistance. These are as follows: 1. Tension and Compression. 2. Combined Stresses. 3. Shear, Riveted Joints and Stresses in Thin-Walled Cylinders. 4. Torsion. 5. Shearing Force and Bending Moment. 6. Stresses in Beams. 7. Deflection of Beams. 8. Statically Indeterminate Problems in Bending. 9. Special Topics Concerning Beams. 10. Stresses Due to Combinations of Direct Stress, Binding and Torsion. 11. Columns. 12. Energy of Strain. 13. Mechanical Properties of Materials.

Regarding the Authors, S. Timoshenko is professor of Engineering Mechanics at the University of Michigan and Gleason H. Mac Cullough holds the same chair at Worcester Polytechnic Institute.

PHOTOCELL APPLICATIONS. By R. C. Walker and T. M. C. Lance. Published by Pitman Publishing Corp., 2 W. 45th St., New York City. Size 5½ by 8½ in., 240 pages, cloth bound. Price $2.50.

The growing industrial importance of photoelectric cells has brought about a large number of books treating the subject in a more or less technical way, but of little service to the practical man. This is the second edition of a book intended to simplify the treatment and prove helpful to the man who must use these tubes and yet does not have the time or inclination to delve deeply into their very complicated theory. With this in mind mathematics have been omitted and theoretical consideration either omitted or greatly simplified. Where necessary, reference to more complicated theory is made to articles or books already published on the subject.

The book itself gives the characteristics of the various cells, methods of use in various circuits for counting, timing and mechanical handling devices, alarms, indicators, safety devices, sound reproduction, photo telegraph, television, scientific instruments, etc. The second, or 1935, edition has been brought up to date by the inclusion of recent applications made since the appearance of the first edition in 1933.

ELECTRIC ELEVATORS. By F. A. Annett. Second Edition. 495 pages illustrated, 6 by 9 in. cloth. Published by McGraw-Hill Book Co., Inc., New York, 1935. Price $5.00.

This second edition of Mr. Annett's book on elevators, first published in 1927 incorporates some of the developments in elevator practice since that time. Chapter I has been considerably enlarged by descriptions of new developments and other parts of the book have been replaced by approximately 200 pages of new material. Two new chapters on control, one on micro-leveling signal control and one on car-switch operation with automatic landing have been added. Car and hoistway door operators, signal systems and selection of elevators—subjects not covered in the previous edition have been treated in three chapters. An entirely new chapter on ropes is included, and the chapter on lubrication has been enlarged with new material on automatic guide-rail lubricators and guide-shoe gibs. The new edition contains about 60 pages more than the old.

The older material is excellent fundamental material on the subject of the modern elevator. It is probably the best treatise on the subject of electric elevators available today.

ELECTRONS, PROTONS, PHOTONS, NEUTRONS AND COSMIC RAYS. By Robert Andrews Millikan. 492 pages, cloth, 5x7½ inches, illustrated. Published by The University of Chicago Press, Chicago, Ill. Price $3.50.

Nobody needs to be informed as to the identity of the author of this book. The name of Millikan in this country has become almost synonomous with science and in recent years at least is heard as often from the pulpit as it is in research laboratories. Beginning with his remarkable experimental work in the isolation of the electron and its exact evaluation in terms of mass and charge, Dr. Millikan has established to his credit as brilliant a series of scientific achievements as anybody in the world except perhaps Einstein. In experimental technique Millikan is a master *par excellence*.

This new book of his is a non-mathematical review of the extraordinary discoveries and developments in present day physics. Beginning with a historical treatment of the theories of electricity and a description of the experiments which led to the isolation and evaluation of the electron, Dr. Millikan describes in detail the subsequent discoveries in atomic physics and in the field of eletromagnetic radiation. Unusually detailed consideration is given the subject of cosmic rays—their discovery and their nature. The more recent discoveries of the neutron, the positron and megatron are discussed and their existence demonstrated by means of remarkable photography taken by means of Wilson Cloud chamber equipment.

While the book is essentially non mathematical, it is not a "popular exposition." It requires an "interest" in the subject and a general knowledge of the use of formulae. All save three of the 16 chapters can be read or at least "browsed" with interest and profit by the general intelligent reader even if he be not versed in the language of the physicist.

PSYCHOMETRICS—A Study of Psychological Measurements. By Johnson O'Connor. Published by the Harvard University Press, Cambridge, Mass. Size 6½ by 9 in., 286 pp., cloth bound. Price, $3.50.

Psychologists as a class have little of direct interest to engineers but Johnson O'Connor is an exception. As an electrical engineer, who became interested in the varying aptitudes of individuals, he has in an unorthodox manner, taken psychology and from it fashioned an engineering tool, a tool as yet crude but offering limitless possibilities.

His work with the General Electric Co. and at Stevens Institute of Technology developed the fact that certain fundamental aptitudes of individuals, mechanical, accounting, etc., are fully developed by the age of about 16 and remain practically unchanged through life. His book, "Born That Way," dealt with the development and application of tests for these fundamental aptitudes. It is not as yet possible to taken an individual and say "You will, or will not, be a success as an engineer" but it is possible, for instance, to say "Your chances of success in this profession are seven out 10" in the same way that insurance statistics are used to predict the chances of an individual 30 yr. old living to the age of 65.

The present book deals with the continuation of Mr. O'Connor's work to the measurement of executive ability, particularly with a year's work under a grant from the Jacob Wertheim Fellowship on Industrial Relations of Harvard University. Seven distinct aptitudes have been isolated or can be measured. These are personality; tonal memory; engineering; accounting; tweezer dexterity; finger dexterity; creative imagination. Two additional elements which can be approximated are: inductive reasoning and visual memory. About one person in 16,000 grades A in all 7 aptitudes and about one in 125 grades A or B in all seven.

A large portion of the book deals with laboratory procedure and highly technical methods of grading of little interest to the general reader. Much of the book is, however, of interest to the general public particularly to those who already know something of Mr. O'Connor's work and the book should be read by everyone interested in psychological work in schools and industry.

AUTOMATIC PROTECTION OF A. C. CIRCUITS. By G. W. Stubbings. 5½ by 8¾ in. 300 pages, 209 figures, cloth. Published by Instruments Publishing Co., Pittsburgh, Pa., 1935. Price $5.00.

The subject matter of this book falls into five main divisions; protective transformers, the interconnection of these transformers, to form protective circuits, relays, modern methods of protecting electrical machinery and transmission networks and finally, the testing of relays and protective circuits. A considerable amount of space is given to a discussion of the theory of protective transformers and their interconnection and to the theory of protective relays before the details of modern protective circuits are considered.

WATER POWER ENGINEERING. By H. K. Barrows. Published by McGraw-Hill Book Co., 330 W. 42d St., New York City. Size 6½ by 9½ in., 745 pp., cloth bound. Price $6.00.

This is the second edition of a comprehensive text on water power rewritten after 7 yr. to include recent developments such as the Kaplan turbine, high voltage, long distance transmission pumped storage plants and revised water power economics made necessary by advances in the steam field where power can now be produced at ¾ of a cent per kw-hr. Although produced primarily as a textbook, the author's practical experience is reflected throughout the book to make it of equal value to the practicing engineer.

About a quarter of the book is concerned with hydrology and steam flow, about half of the book with the power plant itself, including the dam, turbines, generators and auxiliaries and the balance with transmission lines, costs, reports, economics and typical plant descriptions. As a comprehensive treatment of the general subject of water power engineering the book is unequaled, combining as it does the features of a successful text (the author is professor of hydraulic engineering at Massachusetts Institute of Technology) with a practical reference work based on actual field construction and experience.

Power Plant Construction News

Calif., Hueneme—Oxnard Citrus Association, Oxnard, Calif., J. D. McGrath, president, plans installation of electric power equipment, conveyors, loaders and other mechanical-handling machinery in new lemon packing plant at Hueneme, totaling over 100,000 sq. ft. floor space. Cost about $200,000.

Calif., Los Angeles—Metropolitan Water District, 306 West Third Street, will receive bids until August 20 for 237-mile 230-kv. power transmission line, referred to in these columns last month. It will extend from Boulder Dam power plant of Federal Government to group of pumping stations on Colorado River Aqueduct. Work includes steel towers and copper conductors, with alternate bids on reinforced-aluminum conductors, and complete fittings and accessories. Cost estimated close to $5,000,000. F. E. Weymouth is general manager and chief engineer.

Calif., Sacramento—Golden State Soda Works, 1715 Fifteenth Street, plans installation of electric power equipment in new one-story bottling plant, 100x160 ft., at Eleventh and Q Streets. Cost close to $60,000. J. A. Saunders is company architect.

Fla., Pensacola—Hygeia Coca Cola Bottling Works, Inc., 125 East Chase Street, plans installation of electric power equipment in new bottling plant on Palafox Street. Cost close to $90,000, with machinery. Francis P. Smith, Norris Building, Atlanta, Ga., is architect.

Ill., Chicago—Crystal Pure Candy Co., Inc., 2611 West Chicago Avenue, plans installation of electric power equipment in new one-story factory addition, 100x125 ft. Cost about $50,000. R. Bernard Kurzon, 134 North La Salle Street, is architect.

Ill., Freeport—Kraft-Phenix Cheese Corporation, 323 East Stephenson Street, plans installation of electric power equipment in new addition to local plant. Bids have been asked for building units. Entire project will cost close to $200,000. Company headquarters are at 400 Rush Street, Chicago, Ill.

Ind., Evansville—Board of Directors, State Hospital, Lincoln Avenue, Dr. J. H. Hare, superintendent, plans new boiler and engine house at institution. Cost over $40,000, with equipment. Harry E. Boyle & Co., Inc., Furniture Building, Evansville, is architect.

Ind., Evansville—East Dayton Tool & Die Co., 310 East Second Street, Dayton, Ohio, plans installation of electric power equipment in new one-story branch plant at Evansville. Cost close to $40,000. William Schleman is manager.

Iowa, Rock Rapids—City Council is arranging financing in amount of $200,000, about one-half through Federal aid, for municipal electric light and power plant, and electrical distribution system. Black & Veatch, 4706 Broadway, Kansas City, Mo., are consulting engineers.

Kan., Cherryvale—Common Council has plans maturing for new municipal electric light and power plant, and distributing system. Proposed to ask bids soon. Financing is being arranged through Federal aid. E. T. Archer & Co., New England Building, Kansas City, Mo., are consulting engineers.

Ky., Lexington—Board of Trustees, University of Kentucky, plans new power plant at institution for central heating service. Cost estimated at $250,000, with equipment. Financing is being arranged through Federal aid. Frank L. McVey is president.

Me., Portland—City Manager, 389 Congress Street, has plans under way for new steam power plant at City Hospital. Proposed to ask bids for boilers and other equipment soon. E. Leander Higgins, 95 Exchange Street, is architect.

Md., Baltimore—Commanding Officer, Curtis Bay Ordnance Depot, Curtis Bay, Baltimore, plans extensions and improvements in railway electrical system. Estimated cost $31,000, with equipment. Appropriation is being arranged.

Mich., Bay City—Chevrolet Motor Co., 3044 West Grand Boulevard, Detroit, Mich., plans installation of electric power equipment in new additions to plants at Bay City and Saginaw, Mich. Entire project will cost over $350,000. Albert Kahn, New Center Building, Detroit, is architect and engineer.

Mich., Chesaning—Peet Packing Co., food products, has authorized new electric power plant for factory service, and will make alterations and improvements in main plant, with installation of electric power and other equipment. Work will be placed under way at once. Cost about $80,000.

Mich., Detroit—Plymouth Motor Corporation, Mount Elliott Avenue and Lynch Road, plans installation of electric power equipment in four new plant additions, totaling over 100,000 sq. ft. floor space. Cost close to $500,000. Company is a subsidiary of Chrysler Corporation, 341 Massachusetts Avenue, Detroit.

Minn., Faribault—State Commission of Administration and Finance, State Capitol, St. Paul, Minn., plans extensions and improvements in power house at institution at Faribault. Cost about $30,000, with equipment. Proposed to ask bids soon. Pillsbury Engineering Co., 1200 Second Avenue South, Minneapolis, Minn., is consulting engineer.

Miss., Greenwood—At special election, citizens have authorized City Council to arrange for bond issue of $192,000, fund to be used for extensions and improvements in municipal electric light and power plant, and city waterworks, including installation of new equipment. Burns & McDonnell Engineering Co., 107 West Linwood Boulevard, Kansas City, Mo., is consulting engineer.

Mo., Rolla—School of Mines, University of Missouri, plans installation of motors and controls, and other electric power equipment in new mechanical engineering building, geology and ceramics buildings. Fund of $543,500 is being secured through Federal aid.

Mo., St. Louis—G. C. Kern Advertising Sign Co., 2737 Washington Avenue, plans installation of electric power equipment in new one-story addition on Lucas Avenue. Cost close to $30,000. Company specializes in manufacture of electric signs and displays.

N. C., Winston-Salem—Crystal Ice & Coal Co. has taken over four-story building at Mitchell and Wachovia Streets, and will remodel and equip for new ice-manufacturing and cold storage plant. Cost close to $45,000, including equipment.

N. D., Walhalla—Common Council plans municipal electric light and power plant. Fund of about $50,000 will be arranged through Federal aid. C. L. Norton, Bismarck, N. D., is consulting engineer.

Ohio, Columbus—Department of Public Service, City Hall, W. J. Lucks, director, has plans for new one-story mechanical blower and pumping station, 100x190 ft., for waterworks system. Cost close to $300,000, including equipment. Bids are scheduled to be asked soon for four large centrifugal pumping units with accessories, motor-driven blowers and auxiliary equipment.

Ohio, Dayton—Monarch Engineering Co., First Street and Patterson Boulevard, manufacturer of water system equipment, plans installation of electric power equipment in connection with rebuilding of portion of three-story plant, recently destroyed by fire. Loss close to $50,000.

Okla., El Reno—Canadian Mill & Elevator Co. plans installation of power equipment in connection with rebuilding of grain mill and elevator, recently destroyed by fire. Loss over $400,000. Herman K. Schafer is president.

Texas, Dallas—Texas Centennial Exposition, George N. Dahl, technical director, is arranging fund of about $500,000 for installation of electric light and power, water system and other utilities at Centennial Exposition grounds, totaling about 200 acres, in connection with centennial celebration in 1936. Entire project will cost about $15,000,000. Ray Roley is director of Works Division. Proposed to begin work on program early in fall.

Texas, Mathis—Pettus Oil & Refining Co., Pettus, Tex., care of Morris Roberts, Pettus, head, plans installation of power equipment in new oil refining plant at Mathis, where tract of land has been acquired, including pumping machinery, steel tanks and other facilities for storage and distribution. Entire project will cost over $90,000.

Va., Staunton—American Distilling Co., care of Charles B. Ralston, Staunton Chamber of Commerce, Staunton, plans installation of electric power equipment in proposed new distillery on site near city. Plant will comprise several units. A power house will be built. Cost over $300,000.

Wash., Orting—Department of Finance, Budget and Business, State Capitol, Olympia, Wash., Olaf Olson, director, plans extensions and improvements in power house at State Soldiers' Home, Orting. Cost over $40,000, with equipment. Financing is being arranged through Federal aid.

Wis., Superior—Coal Processing Corporation, an interest of Old Ben Coal Corporation, 232 South Clark Street, Chicago, Ill., plans installation of electric power equipment in new coal briquet-manufacturing plant at Superior. It will consist of several buildings. Entire project will cost over $80,000, including machinery.